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CHEMISTRY.—*The carotenoid pigments of the sweet potato* (Ipomoea batatas, Poir.).[1] M. B. MATLACK, Food Research Division, Bureau of Chemistry and Soils.

It has been shown (1, 2) that the sweet potato is a good source of vitamin A. This fact and the natural color of the tuber leads one to suspect the presence of at least one of the four known carotenoids which possess the property of acting as a precursor of vitamin A.

For the purpose of identifying the predominant carotenoid pigments from the sweet potato, the deeply colored variety known as "Porto Rico" was obtained from the local market. Twenty pounds of fresh tubers were ground through a meat grinder and allowed to fall into a salt solution. To this mixture was added an equal volume of ninety-two per cent alcohol. The excess solvent was removed in a press and the process repeated with sixty per cent alcohol. The alcoholic ex-extracts were discarded. Alternate extraction with acetone and petroleum ether yielded solutions which were worked up as follows:

In each case the solution was evaporated to dryness in vacuo and taken up in a small amount of carbon disulphide, and absolute alcohol was added. This yielded a crop of large pleochromatic crystals. On concentration of the mother liquor considerable colorless material separated, and, therefore, saponification with sodium methylate was resorted to. The petroleum ether solution from the saponified material was repeatedly shaken with eighty-five per cent alcohol.

The residue remaining after evaporation of the petroleum ether layer was taken up in a small volume of carbon disulphide, and absolute alcohol was added. Crystals of pigment separated on standing and after concentration of the mother liquor.

Attempts to isolate crystalline xanthophylls from the alcohol phase proved futile because of the small amount of pigment and the large amount of colorless impurities. However, a fraction was obtained which gave a blue color with formic acid and with concentrated hydrochloric acid, indicating the presence of violaxanthin. A spectro-

[1] Food Research Division Contribution No. 340. Received September 20, 1937.

gram was obtained, the absorption maxima of which were very close to that of the mixture known as leaf xanthophyll.

Chromatographic adsorption (3) of the recrystallized pigment on a Tswett column of calcium hydroxide yielded four colored zones rang-

Fig. 1.—Sweet Potato Carotene.

ing from reddish-brown at the top through purple and pale yellow to orange at the bottom. On further treatment of these bands only the

TABLE 1.—POSITIONS OF CENTERS OF THE ABSORPTION BANDS, IN ANGSTROM UNITS.

Carotene		Sweet Potato Carotene		Leaf Xanthophyll		Xanthophyll Fraction from the Sweet Potato	
Room Temperature	Liquid Air Temperature	Room Temperature	Liquid Air Temperature	Room Temperature	Liquid Air Temperature	Room Temperature	Liquid Air Temperature
4815	5000	4825	5010	4760	4900	4755	4895
4490	4670	4500	4680	4430	4580	4440	4590
4230	4375	4230	4375	4190	4300	4190	4310

lowest one produced sufficient material for actual isolation of crystals. These (Fig. 1) melted at 182° and gave absorption maxima[2] as shown in Table 1. These data indicated the coloring matter to be β-carotene.

[2] The writer is indebted to G. E. Hilbert and E. F. Jansen for all of the spectrophotographic work presented in this paper.

It is evident from the above results that the predominant pigment of the sweet potato is beta carotene with a small amount of xanthophylls, one of which is violaxanthin.

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BOTANY.—*The grass genus* Cathestecum.[1] JASON R. SWALLEN, Bureau of Plant Industry.

Cathestecum was described in 1830 by Presl, based on a single species, *C. prostratum*. A second, *C. erectum*, was described by Vasey and Hackel in 1884. Griffiths in 1912 added two more, *C. multifidum* and *C. stoloniferum*, the latter invalid. The genus was placed in Zoysiae by Bentham and Hooker, in Festuceae by Hackel, and in Chlorideae by Griffiths as an ally of *Pentarrhaphis* and *Bouteloua*, the position accepted by Hitchcock and the writer.

Because of insufficient material, the genus has not been well understood. Griffiths noted that the species are variable, but a study of more specimens has made it possible to coordinate specific characters and recognize three additional species, *C. annuum*, *C. varium*, and *C. brevifolium*. *Cathestecum stoloniferum* Griffiths was based on *Atheropogon stolonifer* Fourn. The type (*Liebmann* 588) was not examined by Griffiths, but was later found among specimens kindly lent by the Copenhagen Herbarium in 1915. It is a pistillate plant of *Pringleochloa stolonifera* Scribn. as Scribner supposed, although Fournier described the lower florets as hermaphrodite. The species figured as *C. stoloniferum* by Griffiths in his revision is new, *C. varium*. Griffiths included in *C. erectum* and *C. stoloniferum* some specimens which are here referred to three new species.

Presl's description of the florets as hermaphrodite is scarcely correct since they are nearly always unisexual, sometimes sterile, and very rarely perfect. The genus is complicated by the fact that two of the species, *C. erectum* and *C. brevifolium*, have dimorphous spikes. The two forms are sometimes on different parts of the same plant, as on two adjoining tufts connected by a stolon, but usually they are ap-

[1] Received October 13, 1937.

parently on entirely separate plants. In one form all the florets are staminate, or the upper sterile, whereas in the other the florets of the lateral spikelets are staminate or sterile, and the lower floret of the central spikelet is pistillate, the upper ones staminate, or the uppermost sometimes sterile. The structure of the lemmas is also different in the two forms as described under each species.

A fragment from the type of *C. prostratum* was kindly deposited in the U. S. National Herbarium in 1907 by the Botanischer Garten, Deutsche Universität, Praha, Czechoslovakia. Types of all the other species are in the U. S. National Herbarium.

CATHESTECUM Presl, Rel. Haenk. 1: 294. *pl. 42*. 1830.

Annual or perennial grasses, frequently stoloniferous, with relatively short flat blades and 3 to 10 V-shaped or rhomboid spreading spikes, evenly arranged on opposite sides of the slender flattened axis; spikes falling entire, consisting of three spikelets, the lateral ones 2-flowered, staminate or sterile, rarely pistillate, the upper floret sometimes much reduced; central spikelet 3-flowered, the lower floret usually pistillate, sometimes staminate, very rarely perfect, the upper florets staminate or sterile; first glume short, that of the central spikelet usually flabellate; second glume about as long as the spikelet, acuminate, sometimes minutely lobed and mucronate; lemmas dissimilar, the lower ones cleft about one fourth their length, the awns from between the lobes equaling or slightly exceeding them, the upper ones deeply cleft, the awns villous in the lower part, extending as much as 3 mm beyond the lobes; in spikes wholly staminate, the lemmas all alike; palea nearly equaling the lemma, the nerves excurrent in short awns.

Type species: Cathestecum prostratum Presl.

Distribution: Endemic to Mexico and Central America, one species extending into southern Texas and Arizona.

KEY TO THE SPECIES

Plants annual.
- Culms slender, not more than 25 cm long (usually less than 15 cm), freely branching from all the nodes, the upper one with two or more slender leafless flowering branches. . . . . 1. *C. prostratum*
- Culms coarse, as much as 50 cm long, if less than 25 cm long the upper node with a single inflorescence or sometimes a second hidden in the sheath. . . . . 2. *C. annuum*

Plants perennial.
- Plants cespitose; third floret reduced to a cluster of 5–7 awns on a naked stipe. . . . . 3. *C. multifidum*
- Plants stoloniferous; third floret glumaceous, 3-awned.
  - Lower florets of lateral spikelets pistillate, rarely one of them staminate, the upper usually sterile, rarely pistillate or staminate; lower lemmas usually densely pubescent. . . . . 4. *C. varium*
  - Lower florets of lateral spikelets staminate or sterile; lower lemmas glabrous or only sparsely pubescent. Spikes dimorphous.
    - Lateral spikelets with well developed usually staminate florets; blades, at least some of them, commonly more than 2 cm long, often involute, not becoming curled; stolons comparatively short, conspicuously arching. . . . . 5. *C. erectum*

Lateral spikelets imperfectly developed, the florets mostly sterile, the lemmas reduced; blades flat, mostly 1–2 cm long, rarely longer, becoming curled with age; stolons long, widely spreading, not arching..... 6. *C. brevifolium*

1. Cathestecum prostratum Presl

Cathestecum prostratum Presl, Rel. Haenk. 1: 295. *pl. 42.* 1830. Type collected in Mexico by Haenke, the exact locality not given.

Annual; culms slender in small dense tufts, decumbent-spreading, geniculate at the nodes, freely branching, 4–35 cm long, glabrous; sheaths, except the lowermost, shorter than the internodes, glabrous, or sparsely pilose near the margins and in the mouth, with a pubescent line across the collar; ligule ciliate, about 0.3 mm long; blades flat, acute, glabrous on the lower surface, scabrous and sparsely pilose on the upper, the margins scabrous, 1–5 cm long, 1–2 mm wide, the upper ones and those on the short branches much reduced; inflorescences terminal and axillary from the upper sheaths; spikes ascending or finally spreading, about 4 mm long not including the awns; first glume of lateral spikelets narrow, acuminate, about 2 mm long, that of the central floret broad, scale-like, less than 1 mm long; second glume 3 mm long, hirsute, those of the lateral spikelets acuminate, that of the central spikelet broader, abruptly acute or subobtuse, sometimes lobed, mucronate; florets 3 mm long, dissimilar; lower floret of the lateral spikelets sterile, the lemma glabrous or sparsely pilose, shallowly lobed, the awns equaling or only slightly exceeding them, the upper floret staminate, the lemma cleft to the middle, the awns extending 1 mm beyond the lobes, hispid on the lower part; lower floret of the central spikelet pistillate, the lemma sparsely pilose on the back and on the margins, the lobes about 1 mm long, the awns subequal, 1.5 mm long, scabrous and more or less hispid, the upper florets staminate, the lemmas similar to those of the upper florets of the lateral spikelets, but more deeply lobed, the awns extending 2–3 mm beyond the lobes; stamens 1.5 mm long.

Limestone hills, central Mexico.

MORELOS: Jojutla, *Pringle* 8707.

Without locality, *Haenke* (type).

2. Cathestecum annuum Swallen, sp. nov.

Annuum; culmi ramosi, geniculati, decumbentes, 15–50 cm alti; vaginae internodiis multo breviores, glabrae, marginibus pilosis; ligula ciliata, 0.5–1 mm longa; laminae planae, firmae, acuminatae, infra glabrae, supra pilosae, marginibus scabris, 3–8 cm longae, 2–3 mm latae, superiores reductae; spicae 5–9, 6 mm longae, rachi producta; gluma prima spicularum lateralium acuminata, 2 mm longa, spiculae centralis flabellata; gluma secunda acuminata, 4–5 mm longa, mucronata, hirsuto-villosa; flosculi spicularum lateralium masculi vel steriles, lemmatibus 3.5–4 mm longis, lobatis, aristis quam lobis paulo longioribus; flosculus inferior spiculae centralis femineus, lemmate 4 mm longo, lobato, aristis quam lobis 0.5–1 mm longioribus; flosculi superiores spiculae centralis masculi, glabri, fissi, aristis quam lobis 2–3 mm longioribus, subtus hispidis, superne scabris.

Annual; culms branching, geniculate, decumbent-spreading, rooting at the lower nodes, 15–50 cm tall, glabrous; sheaths mostly shorter than the internodes, glabrous or more or less pilose in the throat and on the margins; ligule ciliate, 0.5–1 mm long; blades flat, firm, acuminate, glabrous on the

lower surface, pilose on the upper, the margins very scabrous, 3–8 cm long, 2–3 mm wide, the upper ones reduced; spikes 5–9, about 6 mm long, the rachis prolonged as a slender hairy bristle; first glume of the lateral spikelets acuminate, 2 mm long, that of the central spikelet minute, flagellate; second glume acuminate, often minutely lobed and mucronate, 4–5 mm long, hirsute-villous at least on the lower half of the keel; florets of the lateral spikelets staminate or sterile, the lemmas 3.5–4 mm long, sparsely pilose on the margins, the lobes 1.5 mm long, the awns equaling or slightly exceeding them, appressed hispid; lower floret of the central spikelet pistillate, the lemma 4 mm long, glabrous or sparsely pilose on the lower part of the back, shallowly lobed, the lateral lobes 1 mm long, the awns strong, extending 0.5–1 mm beyond the lobes, glabrous, the upper florets staminate, the lemmas a little shorter than that of the lower floret, glabrous, deeply cleft, the lateral lobes 2.5 mm long, the awns extending 2–3 mm beyond the lobes, hispid on the lower half, scabrous on the upper; stamens 3 mm long.

Type in the U. S. National Herbarium no. 1720269, collected on open gravelly ground, Balsas, Guerrero, Mexico, altitude 1500 feet, September 9, 1910, by A. S. Hitchcock (no. 6776) (*Amer. Gr. Nat. Herb.* no. 393, distributed as *Cathestecum erectum* Vasey & Hackel).

Prairies and open ground along railroad, Guerrero, Mexico.

GUERRERO: Balsas, *Hitchcock* 6776 (type), 6800. Apipilulco, *Hitchcock* 6697.

3. **Cathestecum multifidum** Griffiths

Cathestecum multifidum Griffiths, Contr. U. S. Nat. Herb. **14**: 360. *f. 24.* 1912.

Type collected at Iguala, Mexico, by Griffiths, September 9, 1909.

Perennial; culms slender, densely tufted, erect or geniculate at the lower nodes, branching, 15–40 cm tall, glabrous, the nodes pubescent; sheaths glabrous, pilose in the throat, the lower crowded, the upper much shorter than the internodes; ligule ciliate, 0.5 mm long; blades flat, acuminate, glabrous or sparsely pilose on the upper surface, the margins very sparsely papillose-pilose, 2.5–8 cm long, 1–1.5 mm wide, the upper culm blades much reduced; spikes, 5–10 mostly secund, 3–4 mm long excluding the awns, the rachis prolonged as a slender bristle; first glume very narrow, acuminate, about 2 mm long, sparsely hirsute; second glume of lateral spikelets acuminate, hirsute, 2.5 mm long, of the central spikelet broader, pilose, notched, with a stout awn nearly 1 mm long from between the teeth; lower floret of the lateral spikelets staminate, the lemma 2.5 mm long, 3-lobed, the lobes mucronate, the upper florets staminate or sterile, 2 mm long, deeply 5-cleft, the divisions aristate; lower floret of the central spikelet pistillate, the lemma 3 mm long, glabrous on the back, the margins sparsely pilose, the tip 3-lobed, the lobes acuminate, sometimes mucronate, the upper florets staminate or sterile, about 2.5 mm long, deeply 5-cleft, sometimes to the base, the lobes narrow, acuminate, the awns 2–3 mm long, the uppermost floret sometimes reduced to awns.

Rocky hills, Oaxaca, Mexico.

OAXACA: Iguala, *Griffiths* without number (type). Oaxaca, *Hitchcock* 6120, 6164. Monte Alban, *C. L. Smith* 950. Ixcotel (Distrito del Centro), *Conzatti* 3607.

4. **Cathestecum varium** Swallen, sp. nov.

Perenne, stoloniferum, stolonibus gracilibus, internodiis 3–15 cm longis; culmi graciles dense caespitosi, ramosi, erecti vel geniculati, 10–15 cm alti;

vaginae glabrae, infirmae basi dense villosae; ligula ciliata, 0.3 mm longa; laminae planae, firmae, acutae, pungentes, infra glabrae, supra scabrae et sparsae pilosae, 1–6 cm longae, 1–2 mm latae, superiores reductae; spicae 3–5, divergentes; gluma prima spiculorum lateralium truncata vel acuminata, 1.5–2.5 mm longa, spiculae centralis flabellata, 1 mm longa; gluma secunda hirsuto-villosa, acuminata, minute lobata, aristis ad 1 mm longis; flosculus inferior spicularum lateralium femineus, lemmate 4 mm longo, dense pubescente, lobato, aristis quam lobis 1–1.5 mm longioribus, flosculus superior neuter, raro masculus vel femineus, fissus, aristis quam lobis 2.5–3 mm longioribus; flosculus inferior spiculae centralis femineus, lemmate eis inferioribus spicularum lateralium simili, flosculi superiores neutri vel masculi, glabri, eis superioribus spicularum lateralium similes.

Perennial, stoloniferous, the stolons slender, wiry, with commonly arched internodes, 3–15 cm long; culms in small dense tufts, slender, branching, erect or geniculate at the nodes, 10–15 cm tall, glabrous; lower sheaths crowded, glabrous, or the lowermost densely villous at the base, pilose in the throat, the upper ones much shorter than the internodes, glabrous; ligule ciliate, about 0.3 mm long; blades flat, firm, acute, pungent, glabrous on the lower surface, scabrous and sparsely pilose on the upper, the margins scabrous, 1–4 cm long (rarely to 6 cm), 1–2 mm wide, the uppermost culm blades much reduced; spikes 3–5, spreading, on a slender flexuous axis 1.5–2 cm long; first glume of lateral spikelets irregular, truncate to acuminate, 1.5–2.5 mm long, that of the central spikelet flabellate, about 1 mm long; second glume hirsute-villous, acuminate or minutely lobed, awned from between the lobes, the awn as much as 1 mm long, that of the central spikelet broader than those of the lateral spikelets; lower floret of the lateral spikelets usually pistillate, sometimes staminate, the lemma 4 mm long, usually densely pubescent but occasionally glabrous, lobed, the lobes about 1 mm long, awned from between the lobes, the lateral awns about equaling them, the central extending 1–1.5 mm beyond them; upper floret usually neuter, rarely staminate or pistillate, sometimes much reduced, the lemma 4 mm long, cleft to below the middle, the awns from between the lobes extending 2.5–3 mm beyond them, villous on the lower part; lower floret of the central spikelet pistillate, sometimes apparently perfect, the lemma similar to the lower lemmas of the lateral spikelets, the upper florets neuter or staminate, glabrous, the lobes and awns as in the upper florets of the lateral spikelets.

Type in the U. S. National Herbarium no. 1720270, collected on dry soil under mesquite, Tehuacán, Puebla, Mexico, August 9, 1910, by A. S. Hitchcock (no. 6072; *Amer. Gr. Nat. Herb.* no. 395, distributed as *Cathestecum stoloniferum*).

Dry rocky hills and in mesquite, Puebla and Oaxaca, Mexico.

PUEBLA: Tehuacán, *Hitchcock* 6072 (type); *Rose & Hay* 5924. San Luis Tultitlanapa, *Purpus* 3569.

OAXACA: Tomellin, *Hitchcock* 6238; *Griffiths* 9764. San Antonio Valley, *C. L. Smith* 958.

5. **Cathestecum erectum** Vasey & Hack.

Cathestecum erectum Vasey & Hack. Bull. Torrey Club 11: 37. *pl 45*. 1884.

Type collected between El Paso and Presidio, Texas, by Havard (no. 2).

Perennial, stoloniferous, the stolons slender, wiry, conspicuously arching, the internodes elongate; culms in small dense tufts, simple or branching,

erect or somewhat geniculate-spreading, 15–30 cm tall, glabrous; lower sheaths crowded, pilose in the throat, the lowermost densely villous at the base, the upper ones more distant, glabrous; ligule ciliate, about 0.3 mm long; blades flat or commonly loosely involute, 3–6 mm long, 1–1.5 mm wide, glabrous on the lower surface, scabrous and sparsely pilose on the upper; spikes usually pale, dimorphous, one form entirely staminate, the other with the lower floret of the central spikelet pistillate, the upper floret and those of the lateral spikelets staminate or neuter, the spikes all of the same kind in a single inflorescence, parts of the same plant (joined by stolons) sometimes with both kinds of spikes; staminate spikes: first glume 1 mm long; second glume acuminate, glabrous or nearly so, that of the lateral spikelets 3 mm long, that of the central spikelet about 4 mm long; lemmas similar, 3 mm long, glabrous, irregularly lobed, awnless or mucronate; pistillate spikes: glumes villous, otherwise like those of the staminate spikes; lemmas of the lateral spikelets similar, 3 mm long, glabrous, cleft to the middle, the awns from between the lobes equaling or barely exceeding them, more or less hispid; florets of the central spikelet unlike, the lower lemma glabrous or sparsely pubescent, cleft one third of the length, the awns from between the lobes glabrous, subequal or the central a little longer, somewhat exceeding the lobes; upper florets similar to those of the lateral spikelets, the awns slightly longer, extending 1–2 mm beyond the lobes; anthers 2 mm long.

Dry rocky hills and prairies, southwestern Texas, Arizona, and northern Mexico to Salvador.

TEXAS: Presidio, *Silveus* 734; *Havard* 30. Hot Springs, *Silveus* 649. Bone Spring (Tornillo Cr.), *Havard* 2. Study Butte (Brewster Co.), *Moore & Steyermark* 3300. South of Marathon, *Swallen* 1123. Without locality, *Nealley* in 1890.

ARIZONA: Without locality, *Palmer* in 1869.

SONORA: Alamos, *Palmer* 705 in 1890. Guaymas, *Palmer* 161 and 345 in 1887; *Hitchcock* 3546, 3551. Yaqui River, *Palmer* 17 and 18 in 1869. Imuris to Santa Ana, *Griffiths* 6834. Hermosillo, *Hitchcock* 3535, 3597. Altar, *Wiggins* 5974; *Pringle* in 1884. Llano, *Hitchcock* 3528.

CHIHUAHUA: Batopilas, *Palmer* 66 in 1885.

SINALOA: Imala, *Palmer* 1459, 1460 in 1891. Culiacan, *Brandegee* 1, 2. "La Noria," *Mexia* 295.

COLIMA: Armeria, *Hitchcock* 7024.

GUERRERO: Rio Balsas, *Orcutt* 4166.

OAXACA: San Geronimo, *Mell* 2144.

GUATEMALA: Zacapa, *Kellerman* 7887.

SALVADOR: La Union, *Hitchcock* 8776.

6. **Cathestecum brevifolium** Swallen, sp. nov.

Perenne, stoloniferum, stolonibus gracilibus, late repentibus, internodiis ad 12 cm longis; culmi caespitosi, graciles, ramosi, erecti vel geniculati, 5–10 cm alti; vaginae glabrae vel sparse pilosae, imae basi dense villosae; laminae planae, acutae, cirratae, infra glabrae, supra scabrae et pilosae, 1–2.5 cm longae, 1–2 mm latae; spicae 3–8, purpureae, divergentes, biformes; spica mascula: gluma prima angusta, 1 mm longa; gluma secunda latior, acuta vel acuminata, glabra vel sparse pilosa, 2.5–3 mm longa, minute lobata, mucronata; lemma inferius 3 mm longum, sparse pilosum, lobatum, mucronatum, lemma superius 2.5 mm longum, lemmata inferiori simile sed lobis longioribus; spica feminea: spiculae laterales imperfectae; gluma prima 1 mm longa; gluma secunda acuminata, 2.5 mm longa, pilosa vel hirsuto-

villosa; flosculi reducti, steriles, raro masculi; gluma prima spiculae centralis 1 mm longa, secunda 3 mm longa, lobata, mucronata, hirsuto-villosa; flosculus inferior femineus, lemmate 3 mm longo, sparse pubescente, lobato, aristis quam lobis paulo longioribus; flosculi superiores masculi vel neutri, lemmata 2.5 mm longa, fissa, aristis quam lobis 1–3 mm longioribus.

Perennial, soloniferous, the stolons slender, wiry, widely spreading, the internodes as much as 12 cm long (usually less than 10 cm), not conspicuously arched as in *C. erectum;* culms in small dense tufts, slender, usually branching, erect or geniculate at the nodes, 5–10 cm tall (rarely to 15 cm), glabrous; lower sheaths crowded, glabrous or sparsely pilose with a tuft of long hairs at the mouth, the lowermost densely villous at the base; blades firm, flat, acute, becoming conspicuously curled with age, glabrous on the lower surface, scabrous and pilose on the upper, the margins scabrous, 1–2.5 cm long (rarely to 5 cm), 1–2 mm wide; spikes 3–8, usually purple, spreading, dimorphous as in *C. erectum;* staminate spike: first glume narrow, 1 mm long; second glume broader, acute or acuminate, usually glabrous or sometimes sparsely pilose on the keel, those of the lateral spikelets 2.5 mm long, that of the central spikelet 3 mm long, minutely lobed, mucronate; lower lemmas 3 mm long, sparsely pilose, shallowly lobed, mucronate from between the lobes, the upper ones 2.5 mm long, similar to the lower but with somewhat deeper lobes; pistillate spikelets: lateral spikelets imperfectly developed, the first glume 1 mm long, the second glume acuminate, 2.5 mm long, pilose to hirsute-villous on the keel, the florets much reduced, sterile, or the lower one rarely staminate; first glume of central spikelet similar to those of the lateral spikelets, the second 3 mm long, minutely lobed, mucronate, hirsute-villous at least on the keel, the lower floret pistillate, the lemma 3 mm long, sparsely pubescent on the back, the lobes one fourth the length of the lemma, the awns from between the lobes slightly exceeding them, the upper florets staminate or neuter, the lemmas 2.5 mm long, deeply cleft, the awns extending 1–3 mm beyond the lobes; stamens 1.3–1.6 mm long.

Type in the U. S. National Herbarium no. 884043, collected on thin gravelly soil, Tequila, Jalisco, Mexico, October 5, 1893, by C. G. Pringle (no. 4559).

Sterile clay or rocky hills and gravelly soil, Jalisco and Colima, Mexico.

JALISCO: Guadalajara, *Palmer* 270 in 1886; *Hitchcock* 7278, 7300; *Pringle* 4046. San Nicolas, *Hitchcock* 7200, 7202. Tequila, *Pringle* 4559 (type). Valencia, *Hitchcock* 7003.

GUANAJUATO: Irapuato, *Hitchcock* 7436.

COLIMA: Colima, *Palmer* 12 in 1897, and 1261 in 1891.

PALEOBOTANY.—Gyrocarpus *and other fossil plants from the Cumarebo field in Venezuela.*[1] EDWARD W. BERRY, The Johns Hopkins University.

Through the friendly interest of Dr. H. G. Kugler, the Trinidad Leaseholds, Limited, forwarded to me in the late summer of 1936, a small collection of fossil plants which had been collected by Dr. Suter of that company near the village of Cuque in the Cumarebo oil

[1] Received September 20, 1937.

field of Venezuela. This field is on the Caribbean coast of the state of Falcon a few miles east of the base of the Paraguana peninsula.

The horizon is the "Mammonal zone" of the Damsite series, which is considered to be of upper Miocene age. The matrix is a fine, light buff or brownish clay, said to be separated by well developed bedding planes of coarser material. The clay is crowded with plant fragments, mostly leaves, and its texture indicates accumulation in quiet water, so that one would expect perfectly preserved leaves rather than the more or less comminuted fragments such as have been found.

The collection is of special interest from several points of view, notably in that it consists of but 26 small pieces of matrix of which half contain nothing that is determinable and the remaining 13 pieces contain not only four new species but four additional known species that can be positively identified with forms described from the Forest sand of the Island of Trinidad, B.W.I. From the character of the material contained in this small collection from Cuque it would seem that a much more extensive and varied suite of plants could be obtained from this horizon.

The Damsite series, according to Liddle, comprises 3000 feet of shales, limestones and sandstones, with extensive marine faunas of upper and middle Miocene age. It is considered to be of about the same age as the Palmarejo formation and younger than the lower Miocene Betijoque formation, from both of which I have described a few fossil plants. It can not be said that the printed information on the stratigraphy of Venezuela is either complete or precise, despite the brave showing of Liddle's useful account, nor is this the place to discuss it even were the facts available.

The present collection is too limited to afford conclusive evidence as to its precise age or environment, but I see no reason for doubting that it is upper Miocene, since the four previously known species were all described from the Forest sand of Trinidad and three of these, *Anacardites americanus*, *Colubrina miocenica* and *Sideroxylon mastichodendroides*, were definitely from the upper part of that formation. Recent collections of fossil plants from Trinidad, not yet described in print show the *Sideroxylon* in the Forest clay overlying the Forest sand, and both the *Sideroxylon* and *Anacardites* at a locality known as the Mud Plant which is said to lie 1700 feet above the plant horizon in the Forest clay.

As will be seen from the following list of species represented, all of the plants are angiosperms and all but one are dicotyledons. They represent 8 genera in 7 families and 7 orders, and it would seem that

the presence of the unique aroid *Caladiosoma* is sufficiently conclusive evidence of a wet tropical climate in a densely forested region, were such evidence thought necessary. Two of the genera, both represented by fruits or seeds—*Melloa* doubtfully, and *Gyrocarpus* more certainly —have not before been found fossil and the latter is of unusual interest.

Monocotyledonae
Arales
Araceae
Caladiosoma miocenica
Dicotyledonae
Rosales
Leguminosae
Mimosites suteri
Leguminosites cuquensis
Sapindales
Anacardiaceae
Anacardites americanus
Rhamnales
Rhamnaceae
Colubrina miocenica
Laurales
Hernandiaceae
Gyrocarpus miocenica
Ebenales
Sapotaceae
Sideroxylon mastichodendroides
Personales
Bignoniaceae
Melloa (?) *cuquensis*

Caladiosoma miocenica Berry

Caladiosoma miocenica Berry, Pan. Am. Geol. **44**: 38, pl. 5, 1915; Johns Hopkins Studies in Geology **6**: 83, pl. 10, figs. 1–4, 1925.

A single fragment collected by Dr. Suter in the Cumarebo field shows a two centimeter length of two stout secondaries with the intervening lamina and with the absolutely characteristic tertiary venation of this species. Had it not been for the more complete material known from Trinidad, B.W.I., it would have been impossible to identify the tiny fragment from near Cuque. As it is the identification is as certain as anything can be on this mundane sphere.

The type was described from the Forest sand of Trinidad and a reference

to the published figures, particularly of the tertiary venation, will convince the student that my statement of the impossibility of making a mistake has not been exaggerated.

Mimosites suteri Berry, n. sp. Fig. 1

Leaflets small, elongate elliptical, somewhat inequilateral, widest medianly, slightly more narrowed at the rounded tip than at the rounded base, apparently sessile. Margins entire. Texture subcoriaceous. Length about 11 mm. Maximum width about 4.5 mm. Midvein stout, straight, prominent. Secondaries numerous, thin, partially immersed, comptodrome.

The species is represented by a complete leaflet and several fragments. It is a type of leaflet not uncommon in the various families of this extensive alliance and can be compared with existing leaflets in *Cassia*, *Drepanocarpus*,

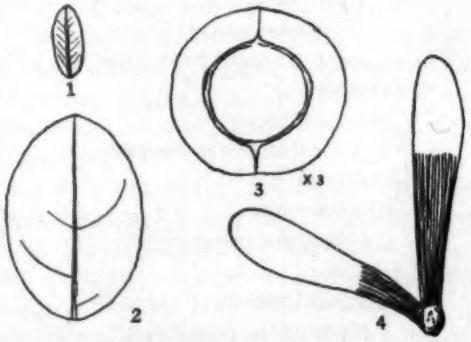

Fig. 1.—*Mimosites suteri* Berry, n. sp. Fig. 2.—*Leguminosites cuquensis* Berry, n. sp. Fig. 3.—*Melloa? cuquensis* Berry, n. sp. Fig. 4.—*Gyrocarpus miocenica* Berry, n. sp.

Platypodium, *Mimosa*, *Caesalpinia*, and many other genera. It can probably be matched by fossil forms described under a variety of names from other regions and different geological horizons, but such comparisons are lacking in significance. It is referred to the form genus *Mimosites* following tradition, and also because the Mimosaceae probably contains more genera with leaflets of this type than do the other families of Leguminosae. The species is named in honor of the collector, Dr. Suter of Trinidad Leaseholds, Ltd.

Leguminosites cuquensis Berry, n. sp. Fig. 2

Leaflets elliptical, nearly symmetrical, widest medianly, with full and rounded entire margins and about equally rounded at the apex and base. No trace of a petiolule. Extremely thick and coriaceous in texture. Midvein very stout, straight and prominent. Secondaries thin, diverging from the midvein at wide angles, regularly curved and camptodrome, almost completely immersed in the leaf substance, as are the tertiaries. Length about 3 cm. Maximum width about 2 cm.

This is a type of leaflet which is frequently referred to *Sophora* and might well represent that genus. It is referred to *Leguminosites* since it might equally represent *Cassia*, *Dalbergia*, *Copaifera* or other unrelated genera in this prolific alliance. Lacking generic certainty there is little point in comparisons with either fossil or living species. Description is attempted since it may have stratigraphic value at some future time.

Anacardites americanus Berry

Anacardites americanus Berry, Johns Hopkins University Studies in Geology 6: 104, pl. 1, fig. 3, 1925.

This species was described from the Forest sand of the Island of Trinidad, B.W.I. A single incomplete specimen is contained in the small collection from near Cuque, Venezuela. It represents a leaflet of some undeterminable member of the Anacardiaceae, *Anacardites* being a form genus proposed especially for material of this sort and the name does not imply any close relationship to the existing genus *Anacardium*. It has recently been found in the Forest clay and at the Mud Plant in Trinidad.

Colubrina miocenica Berry

Colubrina miocenica Berry, Johns Hopkins University Studies in Geology 6: 106, pl. 13, figs. 1–3, 1925.

The type is not uncommon in the upper part of the forest sand of the Island of Trinidad, B.W.I. A single specimen with the base missing is present in the small collection from near Cuque, Venezuela.

Gyrocarpus miocenica Berry, n. sp. Fig. 4

The present species is based upon a single fairly complete specimen and a few small fragments of the rather coriaceous wings. It does not differ appreciably from the immature fruits of the existing *Gyrocarpus jacquini* Roxburg except that the essential part was apparently spherical instead of being the very prolate spheroid of both the immature and mature fruits of the existing species. The thickened covering of the fruit is continued upward to form two, narrow, thickened, spatulate, mostly longitudinally parallel-veined wings which in the fossil specimen are pressed in a divergent position just as are the majority of recent immature fruits in herbarium material. Carpel about 4 mm in diameter. Wings about 4 cm long (estimated) and about 7 mm in maximum width.

The mature fruits of the existing species may become very large and leathery, with opposite wings up to 10 or more centimeters in length, but they show great variation in size and some are scarcely if any larger than the fossils. There seems slight doubt but that the fossil represents a Miocene ancestor of the existing species.

The supposedly single existing species is a stately tree with large quinque-palmate leaves much like those of *Sterculia platanifolia* Linné fils. It is not uncommon in northern South America and is common in the tropics of both the new and old worlds. The variation in the fruits alone seen in comparing

the fossil with the existing forms leads me to doubt the wisdom of referring all of the existing forms to a single botanical species.

The present is the first fossil record of the genus and fulfills the necessary corollary that a genus found in both hemispheres must have had a geological history.

Sideroxylon mastichodendroides Berry

Sideroxylon mastichodendroides Berry, Johns Hopkins University Studies in Geology **6**: p. 124, pl. 13, figs. 4–8, 1925.

This is a common species in the upper part of the Forest sand of the Island of Trinidad, B.W.I. A part of a leaf and its counterpart are contained in the small collection from near Cuque, Venezuela. It has also been found recently in the Forest clay and at the Mud Plant in Trinidad.

Melloa? cuquensis Berry, n. sp. Fig. 3

A single specimen and its counterpart of a small winged seed are doubtfully referred to this genus of the Bignoniaceae on the basis of descriptions and figures as I have been unable to see seeds of the existing species. Seed circular, flatly compressed, about 5 mm in diameter, with a thickened border, surrounded by a narrow fairly thick rim-like wing about 2 mm wide; no venation visible. The hilum and chalaza are at opposite poles of the seed dividing the wing into 2 equal semicircular segments.

The reference to the Bignoniaceae appears to be reasonably certain but the genus is somewhat problematical, for adequate comparisons could not be made because specimens of seeds of the recent genera are seldom preserved in available herbaria. No related fossil forms have heretofore been described. The genus comprises 2 or 3 existing species of lianas ranging from Venezuela to Brazil. Another genus with similar seeds is *Eccremocarpus* with several species of climbing shrubs in the Peruvian region.

PALEOBOTANY.—*Further additions to some fossil floras of the western United States.*[1] ROLAND W. BROWN, U. S. Geological Survey.

During the interval between the writing and publishing of my last paper on this subject[2] new collections have been received, some old collections have been reexamined, and several articles by other students dealing with the fossil floras of the western United States have been published. A survey of this material makes the following additions and changes necessary. Unless otherwise stated, the specimens figured are deposited in the U. S. National Museum.

Populus jenningsi Brown, n. sp. Fig. 3

Description.—A 4-valved, open capsule, 1.8 cm in diameter; valves lance-

[1] Received September 23, 1937.

[2] BROWN, ROLAND W. *Additions to some fossil floras of the western United States.* U. S. Geol. Survey Prof. Paper **186**: 163–206. 1937.

ovate, showing the broad placental lines with raised scars where the seeds were attached.

The matrix in which this fossil was found is similar to that near Missoula, Mont., from which Jennings[3] in 1920 described a small flora assigned by him to the Oligocene. Although he reported two species of *Populus*—*P. smilacifolia* and *P. zaddachi*—it seems now that neither of these belongs to *Populus* but can be referred to another genus. Fruits generally similar to this fossil have been described under one name or another from foreign countries, but so far as I know none has hitherto been reported as *Populus* from strata in the United States.

I take pleasure in naming this fossil fruit for Dr. O. E. Jennings, of the Carnegie Museum, Pittsburgh, Pa.

Occurrence.—Near O'Keefe Canyon, 11 miles northwest of Missoula, Mont. Collected by Earl Douglass.

Populus lamottei Chaney & Elias Figs. 4, 5

Populus lamottei Chaney & Elias, Carnegie Inst. Washington Pub. 476 (1): 35, pl. 4, figs. 4, 5, 1936.

Cercidiphyllum crenatum (Unger) Brown. Chaney and Elias, idem, p. 40, pl. 7, figs. 4, 5.

A reexamination of both the follicle and leaf considered by Chaney and Elias to be *Cercidiphyllum crenatum* shows that they represent *Populus* instead. The features that more particularly distinguish the typical leaves of *Cercidiphyllum* from those of *Populus*, especially *P. tremuloides*, the leaves of which are most nearly comparable to those of *Cercidiphyllum*, are the presence of 3 pairs of lateral veins arising from the top of the petiole, and the departure of the first prominent secondary vein from the midrib at a point above the middle of the blade. In the leaf (Fig. 5) assigned to *Cercidiphyllum* by Chaney and Elias there are only 2 pairs of lateral primaries, and the first strong secondary emerges from the left side of the midrib well below the middle of the blade. The venation is therefore populoid, and the leaf apparently belongs to *Populus lamottei*.

The follicle (Fig. 4) represents the impression of the interior of two almost separated valves of a *Populus* fruit. On the dark placental line the scars where the seeds were attached can be seen faintly. What appears to be venation on the valves may be folds or cracks developed before or during fossilization. This follicle most likely also belongs with *Populus lamottei*, for it was found at the same locality as the leaves. It compares in size with the fruits of a number of cottonwoods, more particularly those of the Southwestern States.

Occurrence.—Pliocene, locality P-42, sec. 3, T. 3 N., R. 25 E., southwest of Beaver, Beaver County, Okla. (Fig. 5); locality P-44, 3½ miles east of locality P-42, sec. 5, T. 3 N., R. 26 E. (Fig. 4).

[3] JENNINGS, O. E. *Fossil plants from the beds of volcanic ash near Missoula, western Montana.* Carnegie Mus. Mem. 8(2): 385–450. 1920.

Fagus pacifica Chaney Fig. 11

Fagus pacifica Chaney, Carnegie Inst. Washington Pub. **346** (4): 108, pl. 10, figs. 6–9, 1927.

Chaney described the leaves and fruit of this species from the Gray ranch, 11 miles east of Post, in the Crooked River basin, Oreg. The impression of the fruit figured here (Fig. 11) comes from the reddish shales along Bridge Creek, Oreg., and is the first evidence of the presence of *Fagus* in the flora from the shales in that area. The flanges of the nut and the three persistent styles are well preserved.

Occurrence.—Oligocene (according to the usage of the U. S. Geological Survey), 9 miles north of Mitchell, Oreg.

Quercus bretzi Chaney Fig. 7

Quercus bretzi Chaney, Contrib. from Walker Mus. **2** (5): 171, pl. 12, fig. 4; pl. 13, fig. 3, 1920.

These oblong to obovate shallowly lobed leaves with broad undulate apexes exhibit characters that suggest relationship to such living American white oaks as the bur oak, *Quercus macrocarpa*, and the swamp white oak, *Q. bicolor*, of the eastern United States. The type figured by Chaney (his pl. 12, fig. 4) is a well-nigh perfect example as such paleobotanic materials go.

Occurrence.—Latah formation (Miocene), Spokane, Wash. Collected by E. E. Alexander.

Quercus columbiana Chaney Figs. 6, 12

Quercus columbiana Chaney, Contrib. from Walker Mus. **2** (5): 170, pl. 13, figs. 1, 2, 1920.

These elliptic to oblong leaves with relatively acute lobes and apexes of a single lobe only slightly larger than the lateral lobes may be compared to a number of living American white oaks, such as the white oak, *Quercus alba*, the valley oak, *Q. lobata*, the Oregon white oak, *Q. garryana*, and the Rocky Mountain white oak, *Q. utahensis*. To which of these specifically, if any, the fossil species may be related, it seems impossible to determine with the scanty material now at hand.

The only other definite representative of the white oak group so far recorded from the Latah formation is *Quercus mccanni* Berry[4] from Grand Coulee, Wash. These leaves are remarkably like those of the chestnut oak, *Q. prinus*, of the eastern United States. The species, *Q. spokanensis* Knowlton,[5] founded on the upper half of a leaf, appears to be the tip of *Castanea orientalis* Chaney.

The leaves of the white oak group are distinguished, in most species, from those of the black oak group by having rounded, blunt lobes, whereas those

[4] Berry, E. W. *A Miocene flora from Grand Coulee, Washington.* U. S. Geol. Survey Prof. Paper 170: 36, pl. 11, figs. 5–7. 1931.

[5] Knowlton, F. H. *Flora of the Latah formation.* U. S. Geol. Survey Prof. Paper 140: 37, pl. 19, fig. 3. 1926.

of the black oaks are generally acute and bristle-tipped. On this basis the black oaks now recognized in the Latah formation are: *Quercus merriami* and *Q. payettensis*. It is possible that these two should be synonymized. The status of two other species, *Q. simulata* and *Q. consimilis*, has not yet been satisfactorily determined.

Occurrence.—Latah formation (Miocene), on Poorman Creek, 22 miles east of Orofino, Idaho (Fig. 6). Collected by Boyd H. Olson. On Potlatch Creek, between Arrow Junction and Juliaetta, Idaho (Fig. 12). Collected by Roland W. Brown.

Cercidiphyllum crenatum (Unger) Brown Fig. 9

Cercidiphyllum crenatum (Unger) Brown, Jour. Paleont. **9** (7): 575–577, pl. 68, figs. 1, 6, 8–10, 1935.—U. S. Geol. Survey Prof. Paper **186**: 175, 1937.

In my 1935 paper I reported the leaves and capsules, but no seeds, of this species from the reddish shales along Bridge Creek, Oreg. The seeds are small and difficult to detect in the reddish matrix, but recently I succeeded in finding one and its counterpart. These small seeds, averaging 5 mm in length, are generally crescent-shaped, the seed portion being long and slender and about the same length as the wing which is attached laterally to the seed at almost a right angle. Small coniferous seeds (Fig. 8) from the same strata should not be confused with *Cercidiphyllum*, because their wings extend in the direction parallel to the linear axis of the seed.

Occurrence.—Oligocene (according to the usage of the U. S. Geological Survey), 9 miles north of Mitchell, Oreg.

Nymphaeites nevadensis (Knowlton) Brown, n. comb. Fig. 10

Spathyema? *nevadensis* Knowlton, U. S. Geol. Survey Ann. Rept. **21** (2): 211 pl. 30, figs. 17, 18, 1900.
Unknown plant. Idem, 212, pl. 30, figs. 16, 24, 25.
Nymphaea diatoma MacGinitie, Carnegie Inst. Washington Pub. **416** (2): 55, pl. 7, fig. 6; pl. 8, 1933.
Nymphaeites diatoma (MacGinitie) Arnold, Contrib. Mus. Paleont., Univ. of Mich. **5** (8): 85, 1937.

The impressions described by Knowlton from the Esmeralda formation of Nevada as an "unknown plant" are on the same piece of rock as those he called *Spathyema*? *nevadensis*. An examination of the surface of a rhizome of a living water lily shows large single petiole scars flanked by aggregates of small root scars; and it is to these, respectively, that Knowlton's specimens correspond.

It is possible that some of the smaller aggregates showing a gradation in size from large to small may be the impressions of the scars on a stem of *Trapa americana*, the nuts of which are abundant in the same strata.

The seeds called *Castalia*? by Berry[6] also from the Esmeralda formation,

[6] BERRY, E. W. *The flora of the Esmeralda formation*.. U. S. Nat. Mus. Proc. **72**(23): 12, pl. 1, fig. 1. 1927.

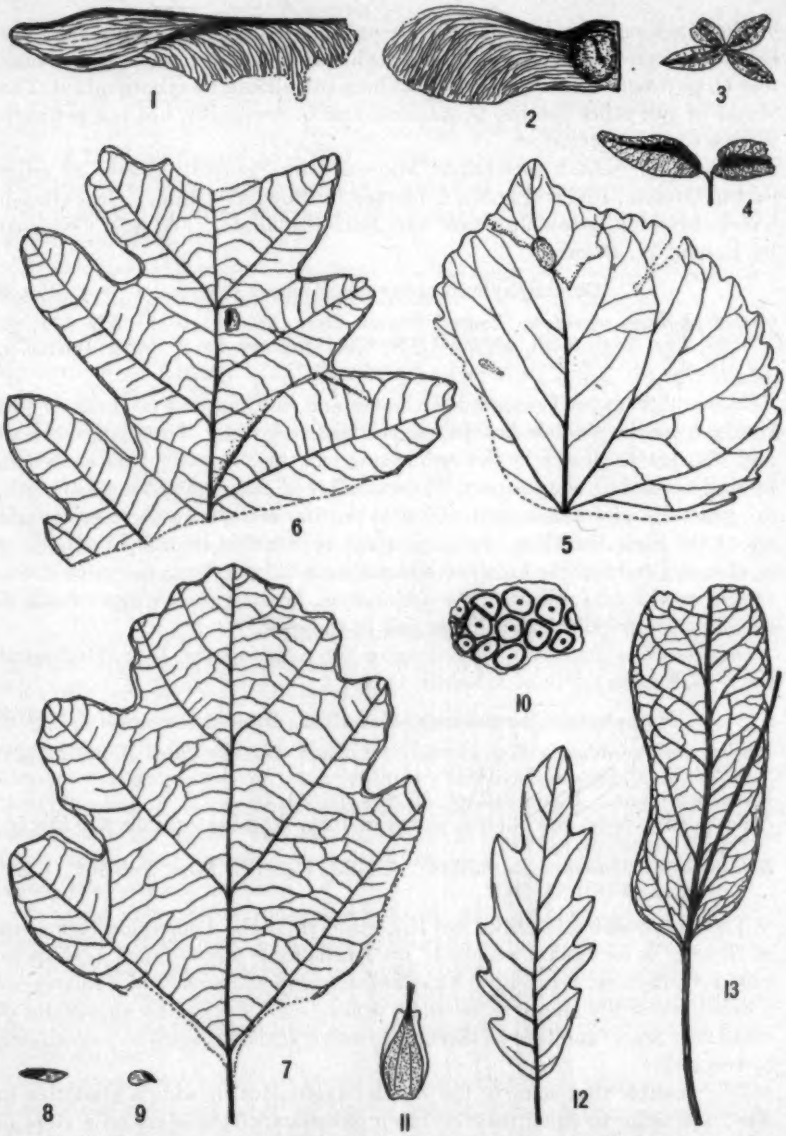

Fig. 1.—*Acer osmonti* Knowlton. Fig. 2.—*Acer scottiae* MacGinitie. Fig. 3.—*Populus jenningsi* Brown, n. sp. Figs. 4, 5.—*Populus lamottei* Chaney & Elias. Figs. 6, 12.—*Quercus columbiana* Chaney. Fig. 7.—*Quercus bretzi* Chaney. Fig. 8.—A coniferous seed. Fig. 9.—Seed of *Cercidiphyllum crenatum* (Unger) Brown. Fig. 10.—Root scars of *Nymphaeites nevadensis* (Knowlton) Brown, n. comb. Fig. 11.—Nut of *Fagus pacifica* Chaney. Fig. 13.—Fruit bract of *Tilia aspera* (Newberry) LaMotte. All figures natural size.

may have been produced by *Nymphaeites nevadensis*, but as their identity is in doubt, they are not now synonymized with the latter species. It is not possible to determine from Arnold's sketch whether his *N. rotundus*, also from Trout Creek, should be synonymized here.

The fossil figured here (Fig. 10) is an aggregate of circular to polygonal root scars showing central pits.

Occurrence.—Miocene. Esmeralda formation, Nev.; Trout Creek, Oreg.; Payette formation, on east side of Snake River, 12 miles west of Weiser, Idaho (Fig. 10). Collected by Roland W. Brown.

Amelanchier dignatus (Knowlton) Brown

Celastrus dignatus Knowlton, U. S. Geol. Survey Bull. **204**: 71, pl. 11, fig. 5, 1902.

Phyllites couleeanus Berry, U. S. Geol. Survey Prof. Paper **170**: 42, pl. 13, fig. 12, 1931.

Amelanchier scudderi Cockerell. Berry, U. S. Geol. Survey Prof. Paper **154**: 252, pl. 55, fig. 4, 1929.

Amelanchier dignatus (Knowlton) Brown, Jour. Paleont. **9**: 577, pl. 69, figs. 5, 6, 1935.—U. S. Geol. Survey Prof. Paper **186**: 176, pl. 53, fig. 11, 1937.

Amelanchier magnifolia Arnold, Contrib. Mus. Paleont., Univ. of Mich. **5** (8): 89, pl. 4, figs. 1, 4, text figs. 2, 3, 1937.

Since my publication of the new combination, *Amelanchier dignatus* (Knowlton) Brown, in 1935, I have compared the specimens there combined with recently acquired new material and have concluded that the types of *A. peritula* Cockerell and *A. scudderi* Cockerell, from Florissant, Colo., and of *A. grayi* Chaney, from Crooked River, Oreg., on both stratigraphic and morphologic grounds, are different from *A. dignatus* and should not be synonymized with it. The three species thus removed from *A. dignatus* may represent a single species, but they at least are uniformily smaller and display sharper apexes than *A. dignatus*. Arnold's *A. magnifolia* is clearly the same as *A. dignatus* as can be seen by comparing his figures with Knowlton's *Celastrus dignatus* and Berry's *Phyllites couleeanus*. The statement that the leaves of the living *A. alnifolia* are *much* smaller than those of *A. magnifolia* is unfortunate. It is true that the average leaf of *A. alnifolia* is smaller, but in my herbarium material of *A. alnifolia* collected in Idaho in 1934 are specimens that easily match Arnold's figures of *A. magnifolia*.

Cedrela merrilli (Chaney) Brown, n. comb.

Rhus merrilli Chaney, Carnegie Inst. Washington Pub. **346** (4): 125, pl. 16, figs. 1, 2, 1927.

Cedrela pteraformis (Berry) Brown, Jour. Paleont. **9** (7): 579, 1935. Referring only to *Acer* sp.? Newberry.— U. S. Geol. Survey Prof. Paper **186**: 179, 1937. Referring only to *Pinus knowltoni* Chaney [Mason].

Although the resemblance between the fossil leaflets called *Rhus merrilli* to those of the living *Rhus sylvestris*, of China, is very striking, as pointed out

by Chaney, two considerations cast doubt on their identification as *Rhus*. First, between the secondaries of *R. sylvestris* there are usually two or more very prominent, short, intermediate secondaries, but in the fossil leaflets these intermediates are thin, few, and commonly, none. Second, the winged seeds of *Cedrela* have been found in the same strata as the leaflets. Because these leaflets can be matched easily with those from living species of *Cedrela* and because they are associated with *Cedrela* seeds it seems more probable that they represent *Cedrela* than *Rhus*.

In 1935 when I made the discovery that the winged seeds theretofore identified as *Acer* and *Gordonia* were in reality *Cedrela*, I was unaware that fossils of this genus were of widespread occurrence in the middle Cenozoic floras of the western States. Since then, remains of *Cedrela*, either leaflets, capsules, or seeds, have been identified in the collections from Florissant, Colo.; Crooked River and Bridge Creek, Oreg.; Mascall formation, John Day basin, Oreg.; Tipton, Sumpter quadrangle, Oreg.; Sucker Creek, Oreg.; 49 Camp, Nev.; Hog Creek, Idaho; and Latah formation, Spokane, Wash. These occurrences cover a large area, geographically, and a span of time from upper Oligocene to early Pliocene. It seems probable therefore, that, instead of a single species, *Cedrela pteraformis*, several species were in existence during that interval. Can these postulated species be distinguished in the fossil materials now at hand?

The earliest western species now known, *Cedrela lancifolia* (Lesquereux) Brown[7] from Florissant, has narrowly lanceolate leaflets and small seeds. It can apparently be separated readily from the other species which exhibit great variability in the size and form of their leaflets and seeds.

The leaflets from Crooked River and Bridge Creek, Oreg., are uniformly elongate elliptic. Those from the Latah formation are in general relatively short, elliptic in outline, with rather blunt apexes. Those from the John Day basin, Trout Creek, and Sucker Creek, Oreg., are lanceolate to broadly ovate-lanceolate with rather acute apexes. As regards the seeds from these several localities I have not yet detected in them such morphologic differences as would serve to distinguish them specifically, but I assume that the capsules and seeds found at any given locality belong with the leaves occurring in the same formation.

The fossil species of *Cedrela* from the western United States, on the basis of differences in foliage, therefore, now appear to be: *C. lancifolia* (Lesquereux) Brown, *C. merrilli* (Chaney) Brown, *C. oregoniana* (Lesquereux) Brown, and *C. pteraformis* (Berry) Brown.

Occurrence.—Oligocene (according to the usage of the U. S. Geological Survey), Gray ranch, Crooked River basin; and 9 miles north of Mitchell, Bridge Creek basin, Oreg.

[7] BROWN, ROLAND W. *Additions to some fossil floras of the western United States.* U. S. Geol. Survey Prof. Paper 186: 178, pl. 60, figs. 3, 4. 1937.

Cedrela oregoniana (Lesquereux) Brown, n. comb.

Ficus? oregoniana Lesquereux, U. S. Nat. Mus. Proc. **9**: 18, pl. 9, fig. 3, 1888.—Knowlton, U. S. Geol. Survey Bull. **204**: 56, pl. 10, fig. 3, 1902.

Sapindus oregonianus Knowlton. LaMotte, Carnegie Inst. Washington Pub. **455** (2): 37, pl. 1, figs. 2, 3, 5; pl. 2, figs. 1–4; pl. 3, figs. 2, 4, 5, 1935.

Sapindus affinis Newberry? MacGinitie, Carnegie Inst. Washington Pub. **416** (2): 60, 1933.

Cedrela browniana Arnold, Amer. Midland Naturalist **17** (6): 1019, fig. 11, 1936.—Contrib. Mus. Paleont., Univ. of Mich. **5** (8): 95, pl. 7, figs. 1, 2, 1937.

Cedrela trainii Arnold, Amer. Midland Naturalist **17** (6) : 1018, figs. 1, 2, 1936.—Contrib. Mus. Paleont., Univ. of Mich. **5** (8): 95, pl. 6, figs. 1–3, 6, 1937.

Apocynum indiana MacGinitie, Carnegie Inst. Washington Pub. **416** (2): 66, pl. 12, fig. 1, 1933.

Cedrela pteraformis (Berry) Brown, U. S. Geol. Survey Prof. Paper **186**: 179, pl. 60, fig. 9, 1937. Including also *Pinus monticolensis* Berry [LaMotte], *Pinus russelli* LaMotte, *Pseudotsuga masoni* MacGinitie [LaMotte], *Libocedrus* sp. Dorf, and *Cedrela pteraformis* (Berry) Brown in Arnold, Contrib. Mus. Paleont., Univ. of Mich. **5** (8): 95, pl. 6, figs. 4. 7–10, 1937.

The leaflets of this species were characterized in the preceding discussion of *Cedrela merrilli*.

Occurrence.—49 Camp, Nev.; Mascall formation (Miocene), John Day basin, Oreg.; Tipton, Oreg.; Trout Creek, Oreg.; Sucker Creek, Oreg.; Hog Creek (according to Dorf, Upper Miocene or lower Pliocene), Idaho.

Cedrela pteraformis (Berry) Brown

Cedrela pteraformis (Berry) Brown, Jour. Paleont. **9** (7): 579, 1935. Referring only to *Carpolithus pteraformis* Berry and *Gordonia pteraformis* Berry. —U. S. Geol. Survey Prof. Paper **186**: 179, pl. 52, fig. 12; pl. 60, figs. 5–8, 10, 1937. Referring only to *Umbellularia dayana* (Knowlton) Berry and *Sapindus armstrongi* Berry.

Cassia spokanensis Berry, U. S. Geol. Survey Prof. Paper **156**: 253, pl. 63, fig. 8, 1929.

The specimen called *Cassia spokanensis* by Berry is the impression of a large capsule that simulates those of *Cedrela*. The seeds of *Cedrela* are abundant in the Latah formation at Spokane, Wash.

The leaflets of this species were characterized in the discussion of *Cedrela merrilli*.

Occurrence.—Latah formation (Miocene), Spokane, Wash.

Acer osmonti Knowlton Fig. 1

Acer osmonti Knowlton, U. S. Geol. Survey Bull. **204**: 72, pl. 13, fig. 3, 1902. —Brown. U. S. Geol. Survey Prof. Paper **186**: 180, pl. 58, figs. 16–18, 1937. (See synonymy and discussion.)

Rhus diluvialis Arnold, Contrib. Mus. Paleont., Univ. of Mich. **5** (8): 93, pl. 5, fig. 4, 1937.

Both the samaras and leaves of this species are clearly of the silver maple (*Acer saccharinum*) type and may be readily identified. The fragment figured by Arnold as *Rhus diluvialis* is the lobe, probably apical, of a leaf of *A. osmonti*. The living *Rhus trilobata* to which this fragment was compared has rounded not sharp marginal teeth as displayed by the fossil. In the Sucker Creek collection of the U. S. National Museum are specimens of *Acer bendirei* Lesquereux, *A. glabroides* Brown, and *A. osmonti* Knowlton.

Occurrence.—Latah formation (Miocene) on Orofino Creek, 20 miles east of Orofino, Idaho. Collected by Boyd H. Olson.

Acer scottiae MacGinitie Fig. 2

Acer scottiae MacGinitie. Carnegie Inst. Washington Pub. **416** (2):62, pl. 11, figs. 4, 8; pl. 12, fig. 4, 1933.

Acer septilobatum Oliver. Dorf, Carnegie Inst. Washington Pub. **476** (2):122, pl. 3, fig. 5, 1936.

The samara figured here (Fig. 2) is almost identical with that figured by Dorf. Both, however, differ somewhat from the type in having the distal end of the wing less prominently upturned. All, having long, squarely truncated, proximal ends (the line of attachment to the twin), seem clearly to belong to the Platanoidea section of *Acer*.

Occurrence.—Diatomite (probably the Idaho formation of Kirkham) in road cut 11 miles south of Horseshoe Bend toward Boise, Idaho. Collected by Roland W. Brown and Don Emigh, Aug. 25, 1934.

Tilia aspera (Newberry) LaMotte Fig. 13

Tilia aspera (Newberry) LaMotte, Carnegie Inst. Washington Pub. **455** (3): 45, pl. 1, figs. 1–3; pl. 2, figs. 1, 2, 1933.

Tilia oregona LaMotte. Idem, 47, pl. 3, fig. 6. [*Platanus aspera* Newberry, U. S. Geol. Survey Mon. **35**: 102, pl. 59, fig. 3. 1898.]

Tilia sp. Arnold, Contrib. Mus. Paleont., Univ. of Mich. **5** (8): 94, pl. 5, fig. 1, 1937.

The fragmentary bract figured here (Fig. 13) is the sole evidence of *Tilia* so far reported from Sucker Creek, Oreg. A portion of the peduncle bearing the fruit is preserved, and that is connate with the midrib of the bract for only a short distance. The peduncle of the bract, it should be noted, is unusually long as compared with those of most living species of *Tilia*.

The leaf originally called *Platanus aspera* Newberry, from Bridge Creek, Oreg., and referred by LaMotte to *Tilia oregona*, is a small leaf of *T. aspera*, because it has the long, coarse teeth and the conspicuously asymmetric base that characterize the latter species.

Occurrence.—Miocene, on Sucker Creek, near the Idaho-Oregon boundary.

Nyssa hesperia Berry

Nyssa knowltoni Berry. Brown, U. S. Geol. Survey Prof. Paper **186**: 184, pl. 62, figs. 1–3, 1937. [Not *Nyssa knowltoni* Berry, U. S. Geol. Survey Prof. Paper **154**: 261, pl. 59, fig. 7, 1929.]

Nyssa hesperia Berry, U. S. Geol. Survey Prof. Paper **170**: 42, pl. 13, figs. 9–11, 1931.

With the acquisition of new material from the Latah formation at Spokane, Wash., it becomes apparent that the specimens figured by me as *Nyssa knowltoni* in 1937 differ so markedly in form and secondary venation from the type described by Berry in 1929 that they should be segregated from the latter and retain the name *N. hesperia*. Whether the type of *N. knowltoni* is in reality a *Nyssa* is problematical. Its form and venation find counterparts in some of the leaves of the living *Magnolia acuminata* and also in the entire, somewhat asymmetric leaflets of *Rhus toxicodendron*.

CHANGES OF NAME AND NEW COMBINATIONS

Acer aquilum Chaney (Contrib. from Walker Mus. **2** (5): 178, pl. 17, figs. 4, 5; pl. 18, fig. 1; pl. 19, fig. 1, 1920)—*Acer negundoides* MacGinitie.

Acer completum Chaney (idem, 179, pl. 18, fig. 2)—*Acer negundoides* MacGinitie.

Acer merriami Knowlton (U. S. Geol. Survey Bull. **204**: 74, pl. 14, fig. 7, 1902) = *Platanus dissecta* Lesquereux.

Acer septilobatum Oliver (Carnegie Inst. Washington Pub. **455** (1): 25, pl. 4, figs. 1, 2, 1934) = *Acer bendirei* Lesquereux. The coarse marginal teeth distinguish this species from the *circinnatum* type to which it was likened, and relate it to the *macrophyllum* type. I can match Oliver's septilobate leaves with specimens of *macrophyllum* I collected near You Bet, Calif., in 1936.

Acer septilobatum Oliver. Dorf (Carnegie Inst. Washington Pub. **476** (2): 122, pl. 3, fig. 5, 1936) = *Acer scottiae* MacGinitie.

Acer sp.? Newberry (U. S. Geol. Survey Mon. **35**: 115, pl. 46, fig. 8, 1898) = *Cedrela merrilli* (Chaney) Brown, n. comb.

Amelanchier magnifolia Arnold (Contrib. Mus. Paleont., Univ. of Mich. **5** (8): 89, pl. 4, figs. 1, 4, text figs. 2, 3, 1937) = *Amelanchier dignatus* (Knowlton) Brown.

Apocynum indiana MacGinitie (Carnegie Inst. Washington Pub. **416** (2): 66, pl. 12, fig. 1, 1933) = *Cedrela oregoniana* (Lesquereux) Brown, n. comb.

Cassia spokanensis Berry (U. S. Geol. Survey Prof. Paper **156**: 253, pl. 63, fig. 8, 1929) = *Cedrela pteraformis* (Berry) Brown.

Cedrela browniana Arnold (Amer. Midland Naturalist **17** (6): 1019, fig. 11, 1936) = *Cedrela oregoniana* (Lesquereux) Brown, n. comb.

Cedrela trainii Arnold (idem, 1018, figs. 1, 2) = *Cedrela oregoniana* (Lesquereux) Brown n. comb.

Cedrela pteraformis (Berry) Brown (part) = *Cedrela oregoniana* (Lesquereux) Brown, n. comb.

Cercidiphyllum crenatum (Unger) Brown. Chaney and Elias (Carnegie Inst. Washington Pub. **476** (1): 35, pl. 4, figs. 4, 5, 1936) = *Populus lamottei* Chaney & Elias.

Diospyros elliptica Knowlton (U. S. Geol. Survey Bull. **204**: 83, pl. 16, figs. 5, 1902) = *Castanopsis convexa* (Lesquereux) Brooks.

Fagus? bonnevillensis Chaney (Contrib. from Walker Mus. **2** (5): 167, pl. 11, fig. 1, 1920) = *Fagus washoensis* LaMotte.

Ficus? oregoniana Lesquereux. Knowlton (U. S. Geol. Survey Bull. **204**: 56, pl. 10, fig. 3, 1902) = *Cedrela oregoniana* (Lesquereux) Brown, n. comb.

Libocedrus sp. Dorf (Carnegie Inst. Washington Pub. **476** (2): 108, pl. 1, fig. 4, 1936) = *Cedrela oregoniana* (Lesquereux) Brown, n. comb.

Liriodendron trilobatum Chaney (Contrib. from Walker Mus. **2** (5): 173, pl. 14, fig. 4) = *Acer negundoides* MacGinitie.

Nymphaea diatoma MacGinitie (Carnegie Inst. Washington Pub. **416** (2): 55, pl. 7, fig. 1, 1933) = *Nymphaeites nevadensis* (Knowlton) Brown, n. comb.

Nymphaeites diatoma (MacGinitie) Arnold (Contrib. Mus. Paleont., Univ. of Mich. **5** (8): 85, 1937) = *Nymphaeites nevadensis* (Knowlton) Brown, n. comb.

Nyssa knowltoni Berry (part) = *Nyssa hesperia* Berry.

Philadelphus bendirei (Knowlton) Chaney. Arnold (Contrib. Mus. Paleont., Univ. of Mich. **5** (8):88, pl. 3, fig. 4, 1937) = *Sassafras hesperia* Berry. Arnold's leaf figured as *Philadelphus bendirei* is a fragment of an unlobed leaf of *Sassafras hesperia*.

Picea? sp. Chaney (Contrib. from Walker Mus. **2** (5): 159, pl. 5, fig. 2. 1920) = *Betula fairii* Knowlton.

Pinus knowltoni Chaney. Mason (Carnegie Inst. Washington Pub. **346** (5): 148, pl. 2, fig. 3, 1927) = *Cedrela merrilli* (Chaney) Brown, n. comb.

Pinus monticolensis Berry. LaMotte (Carnegie Inst. Washington Pub. **455** (5): 110, pl. 5, figs. 1, 4, 1936) = *Cedrela oregoniana* (Lesquereux) Brown, n. comb.

Pinus russelli LaMotte (Carnegie Inst. Washington Pub. **455** (5): 110, pl. 5, figs. 2, 3, 1936) = *Cedrela oregoniana* (Lesquereux) Brown, n. comb.

Populus lindgreni Knowlton. LaMotte (Carnegie Inst. Washington Pub. **455** (5): 115, pl. 5, fig. 1, 1936) = *Populus washoensis* Brown, new name. The type of *P. lindgreni* Knowlton has numerous, relatively small, somewhat crenate, rounded, marginal teeth, whereas the specimen figured by LaMotte has few, large, dentate, blunt-pointed teeth, and a longer, slenderer petiole.

Pseudotsuga masoni MacGinitie. LaMotte (Carnegie Inst. Washington Pub. **455** (5): 111, pl. 2, figs. 6, 7, 1936) = *Cedrela oregoniana* (Lesquereux) Brown, n. comb.

Quercus duriuscula Knowlton. Dorf (Carnegie Inst. Washington Pub. **476** (2): 114, pl. 2, fig. 8, 1936) = *Quercus columbiana* Chaney.

Quercus spokanensis Knowlton (U. S. Geol. Survey Prof. Paper **140**: 37, pl. 19, fig. 3, 1926) = *Castanea orientalis* Chaney.

Quercus sp., unnamed leaf. Berry (U. S. Geol. Survey Prof. Paper **156**, pl. 50, fig. 15, 1929) = *Salix spokanensis* (Berry) Brown.

Rhus diluvialis Arnold (Contrib. Mus. Paleont., Univ. of Mich. **5** (8): 93, pl. 5, fig. 4, 1937) = *Acer osmonti* Knowlton.

Rhus merrilli Chaney (Carnegie Inst. Washington Pub. **346** (4): 125, pl. 16, figs. 1, 2, 1927) = *Cedrela merrilli* (Chaney) Brown, n. comb.

Rhus payettensis Knowlton (U. S. Geol. Survey Ann. Rept. **18** (3): 733, pl. 101, figs. 6, 7, 1898) = *Fraxinus idahoensis* Brown.

Sapindus affinis Newberry? MacGinitie (Carnegie Inst. Washington Pub. **416** (2): 60, 1933) = *Cedrela oregoniana* (Lesquereux) Brown, n. comb.

Sapindus oregonianus Knowlton (U. S. Geol. Survey Bull. **204**: 79, pl. 15, fig. 3, 1902) = *Castanopsis conveza* (Lesquereux) Brooks.

Sapindus oregonianus Knowlton. LaMotte (Carnegie Inst. Washington Pub. **455** (2): 37, pl. 1, figs. 2, 3, 5; pl. 2, figs. 1–4; pl. 3, figs. 2, 4, 5, 1935) = *Cedrela oregoniana* (Lesquereux) Brown, n. comb.

Scale. Chaney (Contrib. from Walker Mus. **2** (5): 181, pl. 22, fig. 5, 1920) = *Libocedrus praedecurrens* Knowlton.

Spathyema? *nevadensis* Knowlton (U. S. Geol. Survey Ann. Rept. **21** (2):

211, pl. 30, figs. 17, 18, 1900) = *Nymphaeites nevadensis* (Knowlton) Brown, n. comb.

Sterculia aceroides Knowlton (U. S. Geol. Survey Prof. Paper **131**: 191, pl. 43, fig. 12, 1923) = *Mahonia marginata* (Lesquereux) Arnold.

Tilia sp. Arnold (Contrib. Mus. Paleont., Univ. of Mich. **5** (8): 94, pl. 5, fig. 1, 1937) = *Tilia aspera* (Newberry) LaMotte.

Tilia oregona LaMotte (Carnegie Inst. Washington Pub. **455** (3): 45, pl. 1, fig. 6, 1935. [*Platanus aspera* Newberry, U. S. Geol. Survey Mon. **35**: 102, pl. 59, fig. 3, 1898]) = *Tilia aspera* (Newberry) LaMotte.

Unknown plant. Knowlton (U. S. Geol. Survey Ann. Rept. **21** (2): 212, pl. 30, figs. 16, 24, 25, 1900) = *Nymphaeites nevadensis* (Knowlton) Brown, n. comb.

ZOOLOGY.—*The histology of nemic esophagi.* VIII. *The esophagus of representatives of the Enoplida.*[1] B. G. CHITWOOD, Bureau of Animal Industry, and M. B. CHITWOOD.

This paper is the eighth of a series (Chitwood and Chitwood, 1934–1936) describing the esophagi of representatives of various groups of the Nematoda. In previous papers representatives of the suborders Rhabditina, Strongylina, Ascaridina, Chromadorina, and Monhysterina have been studied. The present paper deals with representatives of the three suborders of the Enoplida, namely, Enoplina, Dorylaimina, and Diocotophymatina. Of the free-living representatives of this group only *Enoplus*, *Oncholaimus*, *Thoracostoma*, *Cylicolaimus*, and *Dorylaimus* have received any attention by previous authors and even these were not studied from the standpoint of nuclear distribution and nuclear constancy. Among the parasitic forms *Hexamermis*, *Trichuris*, *Trichinella* and *Capillaria* have been studied, but recent observations (Chitwood, 1935) make it necessary to reinvestigate the esophagi of the trichuroids and mermithoids from the comparative standpoint. References to the results of previous authors will be made in the text wherever closely related forms are treated.

The nomenclature and general approach in this paper is the same as that in previous papers and is explained in Part I of the series. As in the sixth paper of the series, data are presented in tabular form, wherever possible, in order to avoid extended descriptions.

Prionchulus muscorum (Mononchidae)

The esophagus of this species is cylindrical, only slightly larger at the posterior end than at the anterior end, and its proximal end surrounds the basal part of the stoma. Grossly, the anterior part differs from the posterior part in being completely muscular, the posterior part containing lobulations of the esophageal glands. The lumen varies with the region of the esophagus but retains a peculiarly modified triradiate character throughout its length.

[1] Received August 13, 1937.

This is due to 6 thickenings of the esophageal lining which serve as attachment points for the radial muscles.

The esophagus cannot clearly be subdivided into regions homologous with those of rhabditids, but in general the muscular part is comparable to the corpus and the glandular part to the bulbar region. There are 36 radial muscle nuclei arranged in 6 groups, the first and second groups (r_{1-12}) being anterior to the nerve ring, and the fourth, fifth, and sixth groups (r_{13-36}) posterior to the nerve ring. The nuclei of the first two groups are considerably smaller than those of the remaining groups.

There are 9 marginal nuclei arranged in 3 groups, the first group (m_{1-3}) being immediately anterior to the third group of radial nuclei (r_{13-18}), the second (m_{4-6}) lying between the fourth and fifth groups of radial nuclei (r_{19-24} and r_{25-30}) and the third group (m_{7-9}) near the base of the esophagus and near the level of the sixth group of radial nuclei (r_{31-36}).

There are 44 nerve cell nuclei, 25 being situated anterior and 22 posterior to the fourth group of radial nuclei. The peculiarities of the pattern of distribution of nerve cell nuclei are distinctive and, with modifications, characteristic of the Enoplina and close relatives.

Five esophageal gland nuclei are present, 1 (g_1) in the dorsal sector and 2 (g_{2-4}) in each of the subventral sectors. The dorsal nucleus lies anterior to the others, near the fourth group of radial nuclei (Fig. 2) while the subventral nuclei are arranged in tandem and posterior to the fifth group of radial nuclei. Each esophageal gland possesses a separate opening close to the nucleus.

The esophago-intestinal valve consists of a short internal triradiate layer of tissue outside of which there is a circular layer, the whole containing 22 nuclei.

Tripyla papillata (Tripylidae)

The esophagus of this species is cylindrical throughout, terminating in a complex, lobular, esophago-intestinal valve. The stoma is rudimentary, the stomatal region being entirely surrounded by esophageal tissue; the lumen is simple, triradiate, and the lining without thickened attachment points for the radial muscles which are dispersed throughout the sectors rather than concentrated in special areas.

There are 36 radial nuclei, 12 marginal nuclei, 45 nerve cell nuclei, 5 gland cell nuclei and 1 nucleus (s_1) of undetermined character. The relative position of most of the nuclei is essentially the same as in *Prionchulus* except that there are 4 groups of marginal nuclei instead of 3, the fourth group being situated anterior to the first group of radial nuclei; the dorsal esophageal gland nucleus (g_1) is situated posterior to n_{39} in *Tripyla* whereas in *Prionchulus* it is anterior to n_{28}.

The dorsal gland nucleus is the largest nucleus of the esophagus; the gland in which it lies opens through the small dorsal denticle at the base of the stomatal region; throughout the anterior part of the esophagus the gland is small and occupies only a small part of the dorsal sector, but becomes lobed and extensive in the posterior part of the esophagus. The nuclei of the first pair of subventral glands are but little larger than the radial nuclei, and those of the second pair are intermediate in size between the first pair of subventral gland nuclei and the dorsal gland nucleus. The first pair of subventral glands have orifices near the level of the dorsal gland orifice, while the second pair appears to have separate orifices situated near the nerve ring, a short distance anterior to their nuclei; no subventral gland tissue extends anterior to the fifth group of radial nuclei.

The posterior lobed structure (commonly termed the "pseudobulb,") at the base of the esophagus apparently represents an unusual development of the esophago-intestinal valve and does not correspond to the base of the esophagus as commonly supposed. The external, lobed part of this structure contains 7 large nuclei and the internal part of this structure contains about 96 small nuclei; some of these nuclei lie in a triradiate tissue surrounded by the external lobed layer, while the others lie posterior to this structure; the anterior (internal) portion is continuous posteriorly with the intestine. The above-described formation is homologous with the "pseudobulb" of *Trilobus* and does not correspond to the bulbar region of other nematodes.

Prismatolaimus sp. (Tripylidae)

The prismatolaim esophagus resembles that of *Tripyla* in being cylindrical and terminating in a massive esophago-intestinal valve; here, however, the resemblance ceases. There is a well developed cylindroid stoma surrounded only at its base by esophageal tissue, and there are three inconspicuous teeth projecting from the base of the stoma which are very similar to those of the oncholaims. The lumen is simple, with very faint indications of terminal dilation of the radii; the lining is unmodified but the radial muscles are concentrated rather than dispersed as in *Tripyla*.

The radial nuclei (30 in number) as well as the marginal and nerve cell nuclei are arranged in a pattern somewhat closer to that found in *Eurystomina* than to that occurring in any other form. The five subequal esophageal gland nuclei are located in the posterior part of the esophagus, and a gland duct extends anteriad through the center of each sector to the anterior end where each opens into the stoma through an orifice in the corresponding tooth. Orifices of the second pair of subventral glands, if separate from the first pair, are probably situated near the nerve ring.

The esophago-intestinal valve is triradiate, massive and apparently contains 13 nuclei.

Aliamus sp. (Alaimidae)

The esophagus of this form consists of a rather elongate anterior part and a moderately short, wide, glandular posterior part. Since the stoma is rudimentary, the stomatal region is surrounded by esophageal tissue. A complete enumeration of the nuclei was not possible. There are 5 subequal esophageal gland nuclei, the nucleus of the dorsal gland being slightly larger than the nuclei of the subventral glands; the orifice of the dorsal gland is situated at the base of the stomatal region while those of the subventral glands are in the posterior part of the esophagus. The radial muscles are concentrated but no attachment points are present. The esophago-intestinal valve is short, triradiate, and appears to contain 9 nuclei.

Metoncholaimus pristiurus (Oncholaimidae)

The esophagus of *Metoncholaimus pristiurus* is cylindrical, and esophageal tissue surrounds only the base of the stoma. Grossly, the anterior and posterior parts of the esophagus are very similar; the part of the esophagus anterior to the nerve ring is uniformly muscular while in the part posterior to the nerve ring the muscle tissue is broken up to a slight extent by lobulations of the esophageal glands. The lumen is simple, closed and triradiate throughout, and the cuticular lining is thin and without modified regions for the attachment of muscles.

There are 12 marginal nuclei arranged in 4 groups of 3 nuclei each, this distribution being similar to that in *Tripyla* except that the third group of marginals is between the third and fourth groups of radial nuclei instead of between the fourth and fifth groups of radials as in *Tripyla*. The radial nuclei are only 27 in number; they are arranged in 4 groups of 6, and 1 group of 3 radial nuclei each. The first three groups undoubtedly correspond to the first 3 groups of radial nuclei in other forms; the fourth group corresponds to

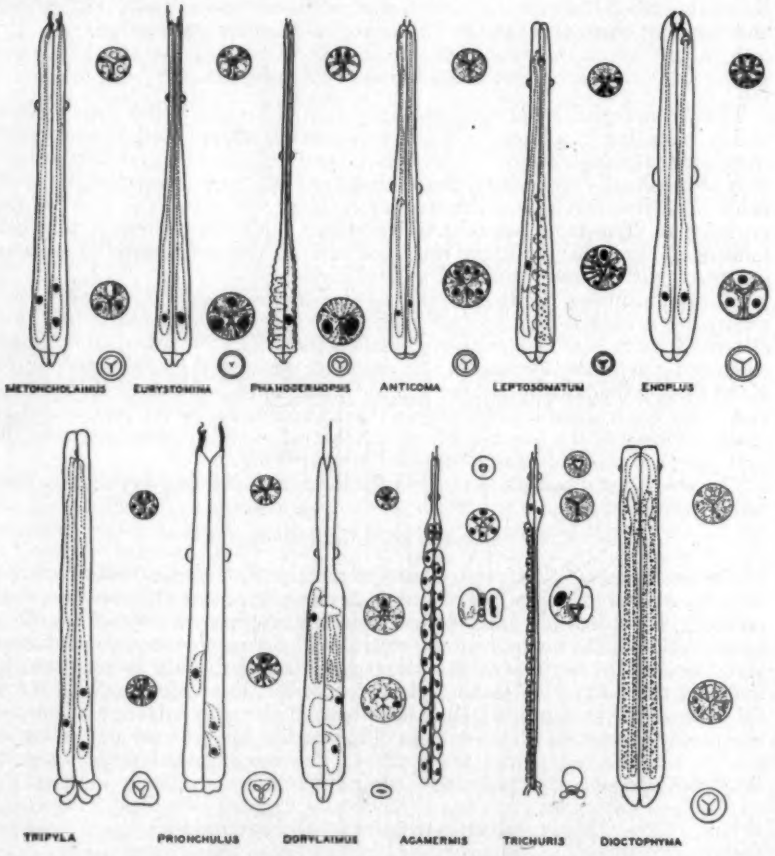

Fig. 1.—Diagrams of esophagi in the Enoplida.

the fifth group in other forms. The last group (r_{25-27}) is composed obviously of giant nuclei resulting from the failure of one nuclear division (Fig. 2). There are 43 nerve cell nuclei which correspond in general to the nerve cell nuclei described in previous forms; the chief differences from forms such as *Tripyla* is that there is 1 additional nucleus (n_{43}) in the mid-dorsal row an-

terior to the peculiar dorsal group (n_{29-32}) and there are 2 less subdorsal nerve cell nuclei at the posterior end of the esophagus (n_{43-44} of *Tripyla*).

Three esophageal glands open into the stoma through the 3 teeth. From their orifices posteriorly, each gland is represented by a small strand of tissue containing the duct in the center of each sector extending approximately to the level of n_{30-31}; posterior to this level they become branched and enter other intermuscular regions of the sectors. Rauther (1907) described *Oncholaimus* sp. (*?vulgaris*) as having 5 esophageal glands, 1 dorsal, 2 lateral, and 2 ventral. The lateral glands according to Rauther, open into the lumen some distance from the anterior end of the esophagus. In *Metoncholaimus pristiurus*, however, the present writers observed 1 dorsal and 4 subventral glands, all 5 nuclei being approximately the same size. In so far as the writers have been able to observe, the 2 subventral glands of each sector have but 1 orifice and their cytoplasm is continuous. If additional orifices are present, they are probably situated near the subdorsal margins of the subventral sectors near n_{30-31}.

The esophago-intestinal valve is elongated, triradiate and consists of an internal trilobed layer containing radial fibers, and a double external layer of circular fibers; the whole is inclosed in a trilobed mass of tissue. The nuclei are numerous (number not determined). A single large nucleus, similar to those of the radial muscle tissue of the esophagus, is situated at the junction of the esophagus and the esophago-intestinal valve.

Eurystomina americana (Oncholaimidae)

The esophagus of this species is of the type generally termed "conoid"; the anterior end is narrow and muscular, gradually increasing in diameter posterior to the nerve ring, the posterior third being wide, glandular, and cylindrical. The lumen is simple, triradiate, but the esophageal lining carries paired cuticular thickenings in the form of attachment points for the radial muscles; these thickenings, similar to those of *Prionchulus*, *Dorylaimus*, *Ironus* and *Cryptonchus*, extend from the anterior end of the esophagus to a short distance posterior to the nerve ring or approximately to the beginning of the glandular part of the esophagus.

The number (12) and arrangement of marginal nuclei is like that in *Tripyla* and *Oncholaimus*. There are 44 nerve-cell nuclei as in *Tripyla* and *Prionchulus*, the first 28 of which are arranged as in those forms, while the remainder differ in many respects in their distribution. Only 30 radial nuclei are present, these being arranged in 5 groups of 6 each. Only 3 nuclei have been identified with certainty as belonging to the esophageal glands; all three of these nuclei are gigantic, the right subventral being considerably larger than the other two. All three glands open through teeth into the cavity of the stoma, the right subventral tooth, like the right subventral gland, being much larger than the other two. In some series there appear to be 2 additional small subventral gland nuclei situated anterior to the large ones.

The esophago-intestinal valve contains only 8 nuclei; the anterior part is triradiate in cross section while posterior part is dorso-ventrally flattened.

Enoplus communis v. *meridionalis* (Enoplidae)

The esophagus of *Enoplus* is cylindrical, slightly enlarged posteriorly, and shows moderate "vesiculation" in the glandular region. Since the stoma is reduced—the stomatal region being indicated by the large bifurcate teeth—this region is entirely surrounded by esophageal tissue. The lumen is simple

and the esophageal lining unmodified (i.e., without cuticular thickenings) throughout the length of the esophagus.

There are 12 marginal nuclei, arranged approximately as in *Tripyla*. Only 33 radial muscle nuclei are present and of these the first 30 comprise the first 5 groups of radial nuclei which correspond to the first 5 groups of *Tripyla*, while the last group of 3 nuclei (r_{31-33}) apparently represents the 6 nuclei (r_{31-36}) composing the sixth group of radial nuclei in that form. The nerve cell nuclei, 44 in number, correspond to the 44 nerve cell nuclei of *Prionculus* and *Tripyla*, but their arrangement differs considerably. There are 3 large similar esophageal-gland nuclei (gl_{4-5}) and 2 smaller subventral gland nuclei (g_{2-3}). Just posterior to the latter an additional pair of ventrolateral nerve cell nuclei (s_{1-2}) are present.

The three large esophageal glands have their orifices at the base of the teeth as Rauther (1907) has already shown in *Enoplus* sp. The vesiculate appearance of the esophagus when viewed in toto is due to the separation of radial muscle fibers by gland tissue. The cytoplasm of the glands is relatively greater in proportion to the muscular tissue than in any of the forms previously described.

The esophago-intestinal valve is short, consisting of an internally trilobed and an externally circular part; the entire valve contains 12 or 13 nuclei (actual number not ascertainable).

Anticoma litoris (Enoplidae)

The esophagus of *Anticoma* is cylindrical and similar to that of *Enoplus;* the anterior part surrounds the stomatal region. Since all of the nuclei have their homologues in *Enoplus*, they are arranged in a practically identical pattern (Fig. 2) and further description seems unnecessary. The gland orifices all appear to be situated at the anterior end of the esophagus, the 2 small subventral glands ending in the marginal regions of the dorsal sector. The esophago-intestinal valve is like that of *Enoplus*.

Rhabdodemania minima (Enoplidae)

The esophagus of *Rhabdodemania* is also like that of *Enoplus*, except that the orifice of the dorsal gland is some distance from the anterior end of the esophagus; the small subventral glands (g_{2-3}) extend nearly to the anterior end as in *Anticoma*, and the large subventral glands (g_{4-5}) have swollen ampulla near the level of their orifices.

Leptosomatum elongatus v. *acephalatum* (Enoplidae)

The esophagus of *Leptosomatum* is grossly conoid, of smooth contour and internally vesiculate. The lumen is simple, triradiate, and the lining thick but unmodified. The relative proportions of muscular and glandular tissue give to the esophagus a consistency somewhat like that observed in *Eurystomina* or *Enoplus*.

There are 2 groups of 3 marginal nuclei, 3 groups of 6 radial nuclei and 18 nerve cell nuclei anterior to the nerve ring as in *Eurystomina* and *Enoplus*. Posterior to the nerve ring nuclear identification becomes extremely difficult due to a great increase in the number of these structures, there being approximately 105 nuclei in the remainder of the esophagus. The ventral gland nuclei have apparently undergone multiple division, since nuclei lie in all possible positions and have little or no definite arrangement. The numerous small nuclei extend into the dorsal as well as the subventral sectors, although

the dorsal gland nucleus has retained its individuality. There is no evidence of atypical division such as nuclear budding, for the small nuclei are all of about equal size. The subventral esophageal gland orifices are near the anterior end of the esophagus while that of the dorsal gland is situated somewhat posterior.

Leptosomatum is provided with pigment spots or "ocelli" which are generally considered to be situated dorsal to the esophagus; the spots are acorn-

Fig. 2.—Tables of nuclear distribution in the Enoplida.

shaped and contain a distinct lens. Schulz (1931) described such ocelli in *Parasymplocostoma formosum*, stating that the lens is a continuation of the external cuticular covering of the body and that the presence of a special cell lying outside of the esophagus is responsible for this formation. In the present form, such is not the case. The pigment spot and lens form a swelling in the wall of the esophagus and are clearly of esophageal derivation. This is a peculiar situation in the origin of photoreceptors, if such they be, and supplies definite evidence of the homology of this type of ocellus with the pigment spots of forms such as *Enoplus*.

Cryptonchus nudus (Ironidae)

The esophagus of *Cryptonchus* grossly resembles that of *Dorylaimus* since it is clearly divisible into a narrow anterior muscular part and a wide pos-

terior glandular part. The long cylindrical stoma is surrounded by esophageal tissue throughout its length and the esophageal lining has marked attachment points for the concentrated radial muscles except in the basal region. The esophageal nuclei seem to follow the pattern seen in *Prionchulus* more closely than to any of the other enoploids, but the dorsal gland nucleus is situated near the level of g_{4-5} instead of being far anterior as in *Prionchulus* and *Dorylaimus*. Apparently the glands have orifices in the posterior part of the esophagus since no tubes extending anteriorly were observed. The rather thick esophago-intestinal valve is very well developed, triradiate, and consists of an anterior part which contains at least five nuclei of obvious esophageal origin followed by a posterior part (cardiac column) containing about 35 nuclei and apparently represents a differentiated region of the intestine.

Ironella prismatolaima (Ironidae)

The esophagus and stoma of *Ironella* are both cylindroid, the latter being surrounded by esophageal tissue and the stomatal region set off from the remainder of the esophagus as a distinct enlargement. The esophageal lining has large thickened attachment points for the radial muscles. The nuclear arrangement is apparently like that of *Cryptonchus*, and the 5 esophageal gland nuclei are subequal but the glands extend anteriorly through the stomatal region nearly to the base of the three bifurcate teeth.

Ironus ignavus (Ironidae)

This form appears to be somewhat intermediate between *Cryptonchus* and *Ironella*, having the gross morphology of *Cryptonchus* but the teeth of *Ironella;* the esophageal glands have orifices anterior to the base of the stomatal region, the subventrals opening near the teeth and the dorsal about midway between the teeth and base of the stoma.

Phanodermopsis longisetae (Enoplidae)

The general outline of the esophagus of *Phanodermopsis*, like that of *Eurystomina*, is of the type described as "conoid," but unlike the latter the margin of the posterior part of the esophagus is "crenate." The crenate appearance is due to development of the esophageal glands and reduction in the relative amount of muscular tissue, the strands of which are set off in relief causing the illusion of cells. The lumen is usually open toward the margins; the esophageal lining is simple.

The nuclear arrangement anterior to the nerve ring in this form appears to agree with that of *Enoplus*, except that the fourth group of radial nuclei is anterior to n_{12-13} instead of posterior to n_{26-27} as in *Enoplus*. Posterior to the nerve ring the number and distribution of nerve cell nuclei and marginal nuclei appear to be as in *Enoplus*, while there is a fifth group of 6 radial nuclei near the level of n_{37-38} (not far from the position of the fourth group of radial nuclei in *Enoplus*), and there appears to be 2 groups of 3 radial nuclei, or a complete sixth group, instead of 1 group of 3 radial nuclei (the diminished sixth group in *Enoplus*) near the posterior end of the esophagus. There are 2 extremely large subventral gland cell nuclei situated not far from the posterior end of the esophagus. Near the anterior end of the glandular region in the dorsal sector there are three bands of tissue each containing a nucleus; these probably are the dorsal and small subventral (g_{2-3}) gland nuclei which in this case have moved to the dorsal sector.

The subventral esophageal glands extend to the anterior end of the

esophagus where they open directly into the lumen. The glandular tissue of the dorsal sector stains very intensely with hematoxylin, and near the level of m_{7-9} the tissue is distinctly subdivided into a dorsal and 2 subdorsal marginal lobes, each of which may represent a separate gland. While no orifice has been observed, it is certain that no glandular material extends anterior to n_{30} in the dorsal sector.

The esophago-intestinal valve is short, internally triradiate and externally circular, the whole containing 8 nuclei.

Soboliphyme baturini (Soboliphymatidae)

The esophagus of *Soboliphyme* is cylindrical and without subdivisions. Since there is no stoma, the anterior end of the esophagus projects slightly into the muscular oral sucker. The esophageal lumen is simple and triradiate throughout its length. The orifices of the three esophageal glands are situated at the extreme anterior end of the esophagus. From each of these orifices a short terminal cuticle-lined duct extends to a short distance posterior to the nerve ring where it bifurcates. Each branch is thick-walled and lined by a peculiar fibrillar layer which is apparently composed of "cilia." Still further posteriad the "cilia" disappear and the branches further subdivide until there may be as many as six parallel tubes in each sector of the esophagus. At times some of the tubules end blindly, while others divide. As a rule, the outer or most marginal tubules in each sector are the ones which terminate blindly while the others continue. There is little difference in the appearance of the glands except near the base of the esophagus. At this point the protoplasm of the dorsal gland tubules is reticulate and the lumen may contain a reticulated mass; the subventral gland tubules appear to have acidophilic granules imbedded in the tubule wall and the protoplasm is more dense than that of the dorsal gland tubes.

Exact information cannot be given regarding the nuclei of the esophagus since only one complete series of sections was available for study, and in places these sections may not have been correctly placed. However, the esophageal glands are multinucleate, each gland containing several hundred nuclei scattered throughout the length of the esophagus. The radial nuclei are in groups of 3, there being 2 groups anterior to the nerve ring and 5 or more groups posterior to that region. The marginal nuclei are likewise arranged in groups of 3. Between the second radial group and the first marginal group of nuclei 11 nerve cells were observed. The determination of other nuclei was difficult because of the great number of esophageal gland nuclei which obscured the picture. The esophago-intestinal valve is triradiate.

Other dioctophymatids

Dioctophyma renale, *Eustrongylides ignotus* and *E. perpapillatus*, none of which has an oral sucker, were all studied in comparison with *Soboliphyme*. The esophagus of *Dioctophyma* is similar to that of *Soboliphyme* except that no "cilia" were observed in the esophageal gland ducts. The dorsal gland ducts, after their primary bifurcation, were never seen to subdivide though every section in an incomplete series of 2000 sections was studied. The esophagi of *Eustrongylides ignotus* and *E. perpapillatus* were also studied in incomplete series, the findings agreeing with those in *Soboliphyme* except that no cilia or granules were observed in the gland tubules. The tubule branching occurs in all three glands and only the outer or marginal tubules in each sector terminate blindly. Slides of these forms always show a marked

differential staining of the glands, the dorsal being acidophilic and the subventrals basophilic. This is particularly marked when stained in a Mallory triple stain, the subventrals being orange or red, the dorsal blue. Subventral gland tubules entering the dorsal sector were only observed in *Dioctophyma* but whether or not this occurs in *Soboliphyme* or *Eustrongylides* is not known; no such case has been observed.

Unfortunately our observations of the esophagi of this particular group, the Dioctophymatina, are not so complete as might be desired. Nevertheless it does serve further to indicate the possible relationships of the forms. In this connection, it may be noted that the dorsolateral mesenteries of the intestinal region begin anteriorly as a single ventral mesentery from the esophagus, which splits before reaching the body wall subventrally. Gradually as one traces the mesentery posteriad the split becomes wider, the single mesentery ultimately forming two subventral mesenteries, two ventrolateral, two lateral, and finally, two subdorsal.

Dorylaimus obtusicaudatus (Dorylaimidae)

The esophagus of this species consists of a short narrow anterior muscular part and a long wide posterior glandular part. There is no distinct stoma in the sense that this structure is present in *Prionchulus*, it having been replaced by a well developed stylet. The stylet is joined at its base with the cuticular lining of the anterior end of the esophagus. The lumen of the esophagus is at first open, wide, and subtriangular (see Chitwood, 1931, fig. 22, No. 5), gradually becoming smaller, the esophageal lining thicker (Chitwood, loc. cit. Nos. 6–7) and with radial thickenings similar to those present in *Prionchulus*. These thickenings are largest in the posterior part of the narrow muscular region but continue throughout the remainder of the esophagus.

There are 36 radial muscle nuclei arranged in 6 groups as in *Prionchulus;* there are 9 marginal nuclei, also arranged as in *Prionchulus;* comparison with the latter form indicates that in *Dorylaimus* $n_{28, 30}$, and $_{41}$ are absent, but it may be that they are merely obscured by glandular tissue. It may also be noted that the group n_{29-32} is more compact than in other forms. A nucleus (st) not present in other forms, is characteristic of the Dorylaimidae. This nucleus, situated in the anterior muscular part of the esophagus is that of the formative or generative cell of the stylet.

Four well developed esophageal gland nuclei, 1 in the dorsal sector (g_1), 2 in the left subventral sector (g_2 and g_4) and 1 in the right subventral sector (g_5), are present. The other esophageal gland nucleus (g_3) is much smaller than the former and easily overlooked. The dorsal gland nucleus lies relatively much farther forward than in *Prionchulus*. Each gland has a separate orifice situated near the level of its nucleus. The dorsal gland is very much lobed and branches of it enter into all sectors of the esophagus. The subventral glands, on the contrary, remain within their sectors and their tubules are relatively smaller.

The esophago-intestinal valve is elongate, dorso-ventrally flattened and contains about 27 nuclei.

Other dorylaimoids

The esophagi of such forms as *Actinolaimus*, *Leptonchus* and other close relatives of *Dorylaimus* appear to be histologically identical to that of the latter form, while that of *Triplonchium* differs considerably. The short bulbar region in *Triplonchium* is literally packed with nuclei, presumably be-

cause all of the nuclei of the more elongated glandular region of *Dorylaimus* are concentrated in less space. The dorsal gland nucleus and those of the first pair of subventrals are subequal in size and smaller than those of the second pair of subventrals. The esophageal lining appears to be simple, unmodified, but this may be due to its extreme minuteness.

Agamermis decaudata (Mermithidae)

The esophagus of *Agamermis decaudata* undergoes considerable transformation during its development. In order to understand satisfactorily the esophagus of the later parasitic stages and adults a brief résumé of the earlier stages is necessary.

Christie (1936) described the morphology of the various larval stages of *A. decaudata* and the essentials of this description are as follows: In the preparasitic larva the digestive tract consists of a stylet followed by the esophagus and intestine. The anterior part of the esophagus is narrow, muscular, surrounded near the middle of its length by the nerve ring; the narrow anterior part is followed by a short elongated muscular swelling posterior to which there is a long glandular region. In the latter region the esophagus proper is very narrow and surrounding it are three large elongated esophageal glands and 2 rows of 8 smaller cells, the stichocytes. The largest gland is unicellular, right subdorsal in position, and extends from the esophageal swelling to the base of the esophagus; the two unicellular subventral esophageal glands are left subventral in position and extend posteriorly from the esophageal swelling to about $\frac{1}{4}$ the length of the glandular part of the esophagus; the stichocytes extend from slightly anterior to the base of the subventral glands to the posterior end of the esophagus. At this time the intestine does not extend anterior to the base of the esophagus.

Shortly after entrance into the host the three esophageal glands become atrophied while the stichocytes become larger and the intestine begins growing anterior to the base of the esophagus.

The present study was based on partially grown parasitic larvae about 5 mm long (approximately 1 to 2 days in host) at which stage the external cuticle is still thin, though otherwise the larvae is in much the same condition as it is at the time of its emergence from the host.

At this stage the esophagus is no longer distinctly muscular in any region, the elongated swelling posterior to the nerve ring has disappeared, and the trophosome extends anteriorly nearly to the level of the anterior esophageal glands. The stichocytes are large, forming a double row of elongated cells with their ends touching one another.

Anterior to the nerve ring the lumen is internally hexagonal, the lining thick and externally rounded to subtriangular in cross section. There is a group of 9 small nuclei near the oral opening, which appear to be radial or marginal in character. The surrounding esophageal tissue is spongy, without apparent symmetry. Posterior to these nuclei, there are 12 large rather irregularly arranged nuclei (r_{1-12}) anterior to the nerve ring. Between the nerve ring and the orifice of the dorsal esophageal gland the esophageal nuclei, lining, and general structure are like that part anterior to the nerve ring. In this region 15 large nuclei (r_{13-27}) and at least 5 nerve cell nuclei (n_{1-5}) are present. The region of the esophageal glands contains 4 nerve cells (n_{6-9}) and 3 large nuclei (r_{28-30}) in addition to the 3 gland nuclei (g_{1-3}). Each gland has at least 1 distinct orifice, sometimes several.

Posterior to the gland nuclei (g_{1-3}), the chief part of the esophageal tissue containing the esophageal lumen is flattened between the two large rows of

stichocytes. The tissue surrounding the lumen (which corresponds to the ordinary muscular and fibrous parts of the esophagus) contains 18 large nuclei (r_{31-48}) and 2 nerve cell nuclei (n_{11-12}) between the beginning of the stichosome and the posterior end of the esophagus. The esophageal lumen in this region varies in shape but is for the most part rounded; the esophageal lining is thin and without evidence of triradiate or hexaradiate structure.

Each stichocyte is a large unicellular gland having 1 distinct orifice from which a wide irregular tubule extends into the cell where it branches into many smaller tubules. Posteriorly the esophageal lumen ends blindly in a mass of fibrous esophageal tissue and apparently is without direct connection with the intestine or trophosome. Several minute nuclei present in this region may correspond to the nuclei of the esophago-intestinal valve of other nematodes.

Discussion.—The fact that the 3 primary esophageal glands are highly developed in the preparasitic larva and undergo atrophy after entrance into the host indicates that they probably function during penetration into the host. The hypertrophy, during larval development, coincides with the time in parasitic life at which most rapid development takes place and, these glands are considered as being the chief digestive glands during this stage of of life. When the larva reaches maturity the stichocytes undergo reduction in size, and in the adult stage, when no nourishment is taken in, their pores are no longer apparent.

Regarding the number and arrangement of non-glandular nuclei, it may be pointed out that the number of large nuclei (r_{1-48}) corresponds with the total number of radial and marginal nuclei in *Dorylaimus* but the observed number of nerve cells (n_{1-12}) and nuclei of unknown nature (the possible nerve cell nuclei (s_{1-9})) is much smaller. Perhaps some of the nuclei were overlooked, or perhaps the decreased number may have been due to degeneration. Since radial and muscular fibers are only represented by a spongy network in the parasitic stage studied, normal function of the esophagus as a sucking organ is impossible; hence, nerve cells would be of little benefit in coordinating muscular activity.

Trichuris ovis (Trichuridae)

The esophagus of *Trichuris* consists of an anterior part (corpus) and a greatly elongated posterior part (bulbar region) embedded in a series of gland cells, the stichosome. The anterior part is divisible into sections, the first part being entirely muscular, narrow, slightly constricted at the nerve ring and the second part glandular and rather wide. The lumen of the entire corpus is definitely triradiate, without special modifications. A group of 3 minute nuclei (s_{1-3}) and a group of somewhat larger nuclei (c_{1-3}) are situated anterior to the nerve ring. The esophagus gradually becomes larger in diameter posterior to the nerve ring and a group of 3 marginal nuclei (m_{1-3}) is followed by a group of 6 radial nuclei (r_{1-6}). The first glandular substance makes its appearance in the esophagus just posterior to the radial nuclei. Between this level and the beginning of the stichosome 2 additional groups of 3 radial nuclei (r_{7-9}) (r_{10-12}), 6 smaller nuclei (s_{4-9}), and 3 large gland cell nuclei (g_{1-3}) are situated. In one of the 6 series studied a fourth gland cell nucleus, slightly smaller than the others, appeared to be present. The esophageal gland nuclei (g_{1-3}) extend anteriorly to within about 50μ of the beginning of the enlarged portion of the corpus. Sometimes what appeared to be orifices were observed near this level but it cannot be definitely stated

that what was observed were actually orifices of the esophageal glands. There was no evidence that any ducts extend anteriorly beyond this level.

In the posterior or stichosome region the esophagus is embedded in a single row of large subcylindrical cells or stichocytes. The lumen varies from subtriangular to triradiate to hexaradiate. The wall and external covering of the esophagus both retain their identity throughout the stichosome region. Large and small nuclei are present within the wall, the large nuclei corresponding to the radial nuclei of the anterior part of the esophagus and the small nuclei possibly corresponding to the s or c types or nuclei of the esophagus of other forms. Contrary to the general opinion, the esophagus is muscular and capable of dilation and contraction throughout its length. In areas close to the large radial nuclei only sarcoplasm is present but further distant, where the nucleus would not interfere with muscular activity, well developed radial fibers may be demonstrated by proper staining.

The numerous large stichocytes forming the stichosome or "cell body" are actually esophageal glands. Each cell has a duct through the wall of the esophagus to the lumen and this duct branches into many tubules within the cell. The orifices of the stichocytes alternate, one entering from the left subventral side, the other from the right subventral side, etc. The stichocytes are more numerous in *Trichuris* than in *Agamermis*, and apparently their number may vary within a limited range.

Posteriorly the esophagus joins the intestine through a dorsoventrally elongated esophago-intestinal valve. The most distal stichocyte often protrudes posteriorly past the beginning of the intestine, and at the same level 2 large cells (cc.) are attached to the esophagus and intestine. The nature of these cells is not known; they do not appear to be in intimate protoplasmic connection with the intestine, esophagus, or stichosome, and stain differently from all three of these structures; it is suggested, without great conviction, that these cells may be coelomocytes.

Discussion.—Ward (1917) divided the Nematoda into two groups, Myosyringata and Trichosyringata, assuming for the latter group, which included *Trichuris* and *Mermis*, a fundamentally peculiar esophagus formed as an intracellular tube. However, Chitwood (1930) has pointed out that the esophagi of *Trichuris* and *Trichinella* are triradiate and not intracellular tubes as stated by previous writers.

Concerning the nature of the stichosome or cell body, Rauther (1918) considered the stichocytes as gland cells and observed orifices of the first 2 or 3, but no orifices thereafter. Chitwood (1930) overlooked the orifices of these glands and considered the stichosome as an outgrowth of the intestine. G. W. Müller (1929) and Christenson (1935) considered the stichocytes as intimately connected with the hypodermis. Later Chitwood (1935) corrected these errors, finding the stichocytes to be esophageal glands. Additional intraesophageal glands are described here for the first time.

As regards the nature of feeding trichurids, the following are several points of interest:

(1) Fülleborn (1923) described a stylet in the larvae of *Trichuris* and Li (1933) observed this structure in adult *Trichuris*. This point has been verified by the present writers. Stylet bearing nematodes usually feed by pressing the head against a membrane, protruding the stylet through the membrane and sucking the material through the stylet into the esophagus.

(2) The esophagus in trichuroids always has a well developed anterior muscular part and in this paper it has been shown that muscles capable of the dilation necessary for sucking are present in the posterior part.

(3) Both Müller and Christenson regarded the stichosome a hypodermal development, which is contrary to our observations. Müller considered the bacillary bands as regions of "feeding pores," while the present writers agree with Jägerskiöld (1901) in classifying them as hypodermal glands.

Christenson is of the opinion that the stichosome is a hypodermal development since he states: "The writer . . . is of the opinion that they (the stichocytes) originate from the hypodermis since in *Capillaria aerophila* they are intimately connected with that layer. It seems possible that during the development the alimentary canal first forms and specializes into its component parts. As the epithelogenous muscles develop the muscle fibers arise in the subcuticular portion of the hypodermal cells, and the nucleus and cell body are 'pushed' toward the center of the worm where they enlarge and surround the esophagus, all the while maintaining their relationship with the hypodermis through anastomising processes. In this fashion their origin would be somewhat similar to that of the esophageal glands which are formed in many nematodes." The supposed connection between the stichosome and bacillary band, namely the mesenterial tissue is *isolation tissue* and belongs to neither the esophagus nor the body wall, but is mesenchymatous in origin (see Chitwood & Chitwood, 1937) and contains its own nuclei; furthermore, as shown by Martini (1903–1910) the musculature is not epithelogenous but *mesodermal* and finally, the esophageal glands of nematodes are formed from the stem cell and may in development leave the esophageal wall, but they are always in the esophagus at the time the esophageal primordium is laid down.

(4) Several investigators, including Guiart (1908) found blood engorged specimens of *Trichuris*, while G. W. Müller (1929) considered the esophagus as non-functional; apparently Müller was unaware of previous reports. G. G. Smirnov (1936) after a comprehensive survey of the literature concluded that there was no convincing evidence that trichuroids feed on blood; he was also unable to obtain such evidence from sectioned material. In one series of sections studied by the present writer red corpuscles were numerous in the esophageal lumen, a total estimated at about 700; this observation confirms the findings of Guiart.

These above facts together with the extreme minuteness of the esophageal lumen indicate that *Trichuris* is possibly an obligatory hematophagous animal; this is supported by the reports of Whipple (1909) and of Garin (1913) of the occurrence of *Trichuris* of hemolytic enzymes.

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ENTOMOLOGY.—*The beetles of the subfamily Chasmatopterinae in the New World (Coleoptera: Scarabaeidae).*[1] LAWRENCE W. SAYLOR, Bureau of Biological Survey. (Communicated by E. A. CHAPIN.)

According to the Junk and Leng Catalogues the tribe Chasmatopterini includes seven genera, four of which are listed from the United States. Present studies, however, indicate that of these four genera, one (*Oncerus*) belongs near the subfamily Aclopinae because of the presence of the exposed labrum, which is foreign to the rest of the Melolonthinae; a second (*Podolasia*) is very different in general habitus and does not belong here, as is explained more fully below; the third (*Pseudacratus*) is a synonym of the fourth (*Chnaunanthus*) and

[1] Received October 5, 1937.

the latter then is the only representative of this group in the New World.

I have seen but three examples of *Podolasia*, one in Mr. E. G. Linsley's collection from Brownsville, Texas, and two in the United States National Museum from "Ft. Ringgold (May and June)," and from "near Hansville, base of Henry Mts., Utah, June, E. Bowles collector." Although the mouthparts and connate abdominal segments appear to place this genus with the Chasmatopterinae the general habitus and the remaining morphological features are radically different and prevent its inclusion in this subfamily. Until specimens can be dissected, the exact place of the genus in the scheme of classification must remain in doubt. It is quite probable, however, that *Acoma* will be its nearest relative.

Oncerus belongs near the Aclopinae, and a paper on the species of this and a related new genus is about ready for publication.

While the Chasmatopterinae is listed in our catalogues as a tribe under the subfamily Melolonthinae, a careful examination of the characters forbids its placement with that group. All species of the Melolonthinae proper have at least the last two or three spiracles in the chitinous abdominal plates while the present genera, *Chnaunanthus* and *Chasmatopterus* (as well as *Oncerus*) have the spiracles entirely in the membrane, and therefore are more closely related to the Glaphyrinae, Pleocominae and others. These cannot be placed with *Acoma* of the Pleocominae which also has the spiracles in the membrane because of many differences: the labrum is small but near the clypeal apex in the Chasmatopterinae, but very small and far back from the apex in *Acoma;* the antennae are of entirely different conformation in the former, being very short and with the small, oval club composed of segments capable of fitting one into another, and the club is much shorter than the funicle, while the latter (*Acoma*) has the antennae quite long, much longer than the funicle and the segments are not capable of folding one into the other; also, the abdominal segments in the Chasmatopterinae are connate with the sutures nearly or entirely effaced, while *Acoma* has entirely free ventral abdominal segments and the sutures are quite obvious. Other characters of less importance but much supplementary value are the cleft tarsal claws, small eyes, and diurnal habits of *Chnaunanthus* as opposed to the entirely simple claws and the very large eyes, fitted for nocturnal life, of *Acoma*.

Many characters, such as the position of the spiracles, and es-

pecially the absence of the large exposed mandibles and labrum prevent the placement of the Chasmatopterinae with either the *Glaphyridae spuriae* of Burmeister or the Aclopinae, so that a separate subfamily is necessary for its reception. This new subfamily may be called the Chasmatopterinae, and is characterized by the position of all the spiracles in the abdominal membrane, the hidden labrum and small concealed mandibles, the cleft tarsal claws, the small oval antennal club and the semiconnate or connate ventral abdominal segments.

The genus *Chnaunanthus*, our sole representative of the subfamily, is represented by three species, one of which is here described as new. In contrast to the published statements of authors that in this group there is no front tibial spur I wish to point out that such is almost always present in the female, and *may* be absent in the male. It is more likely that it is so fragile as to be readily lost through wear. In *Chasmatopterus* the front tibial spurs are usually present and conspicuous.

The two common genera of the subfamily may be more completely separated as follows (I have not seen specimens of the remaining two genera in the subfamily, the African *Microdoris* Burm., and the Chinese *Diphycerus* Fairm.):

Front inner tarsal claw of male deformed, the outer as in the remaining claws on the other legs; front femora bidentate; labrum in lateral view very conspicuous, especially in ♀; front tibial spur always large and conspicuous. (European.).....*Chasmatopterus*

Front inner claw of male not deformed, of the same size and shape as the remaining claws; front femora tridentate; labrum in lateral view very small and hardly noticeable; front tibial spur usually lacking. (American.).....*Chnaunanthus*

Dr. E. A. Chapin of the National Museum has made helpful suggestions in the present studies, and the author also wishes to thank him for the loan of material.

CHNAUNANTHUS

Chnaunanthus Burmeister, Hand. Ent. **4**: 31, 1844.—Lacordaire, Gen. Col. **3**: 221, 1856.—Bates, Biol. Cent. Amer., Col. **2**(2): 130, t. 8, f. 2.—Dalla Torre, Coleop. Cat. **45**: 7, 1912.

Acratus Horn, Trans. Amer. Ent. Soc. **1**: 165, f. 1, 1867.—Dalla Torre, Coleop. Cat. **45**: 7, 1912.

Pseudacratus Dalla Torre, Coleop. Cat. **45**: 7, 1912.

Oblong-oval, little wider behind, polished, pilose above. Ligula separate from mentum. Antennae 9-segmented; club 3-segmented, short and oval. Front coxae conical. Front femora tridentate. Tarsi with all claws cleft, the upper tooth noticeably shorter; tarsi noticeably longer than the tibiae, the

latter usually strongly spinose. Head slightly longer than thorax; clypeus convergent anteriorly. Thorax slightly subangulately rounded at sides, margins ciliate. Elytra not quite twice as long as thorax. Pygidium usually hidden from above. Abdominal segments closely connate, sutures barely

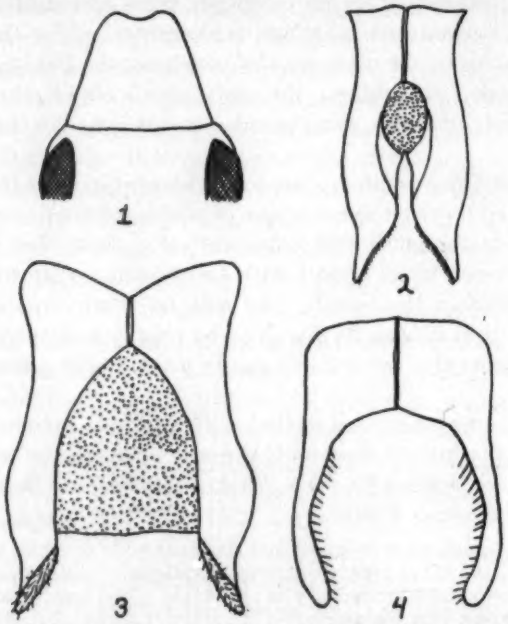

Fig. 1.—Head of *Chnaunanthus flavipennis*, showing clypeal shape. Fig. 2.—Male genitalia of *Chnaunanthus chapini*. Fig. 3.—Male genitalia of *Chnaunanthus discolor*. Fig. 4.—Male genitalia of *Chnaunanthus flavipennis*.

visible in the male and apparently absent in the female. Male abdomen in lateral view concave, that of female convex.

KEY TO THE SPECIES

1. Hind angles of the thorax broadly rounded, not at all subangulate; clypeus wider than long but not distinctly so, the apex always deeply emarginate; female pygidium with two longitudinally-impressed subapical foveate areas before apex and these often converging, forming a U-shaped sulcus. (Utah and Arizona.).....*flavipennis*
   Hind angles of thorax rounded but subangular; clypeus usually noticeably wider than long; apex of clypeus often but little emarginate; female pygidium not as above.....2
2. Pygidium of male longer than wide, very densely hairy all over; female pygidium usually noticeably concave at apical fourth, always densely hairy all over. (Mexico.).....*discolor*
   Pygidium of male wider than long, moderately hairy at base, subglabrous apically; female pygidium flattened, with no trace of any apical sulci, moderately densely hairy near base, subglabrous apically. (Calif. and Oreg.).....*chapini*

Chnaunanthus flavipennis (Horn)

Acratus flavipennis Horn, Trans. Amer. Ent. Soc. I: 165, 1867.
Pseudacratus flavipennis Dalla Torre, Coleop. Cat. 45: 7, 1912 (new combination).
Chnaunanthus palmeri Horn, Proc. Calif. Acad. 4: 393, 1894.—Dalla Torre, Coleop. Cat. 45: 7, 1912. (New synonymy).

This species may be quickly placed by the key characters and the male genitalia. The elytra vary from testaceous to piceotestaceous, and the thorax from rufous to rufopiceous.

I have seen 11 specimens, including a pair of Horn's paratypes; of these all but 2 Arizona specimens are from Utah. I have been able to examine the types of *Pseudacratus flavipennis* through the courtesy of Mark Robinson and the authorities of the Philadelphia Academy of Natural Sciences, and was able to confirm the suspicion I have had for some time that both genus and species are synonomous with the above, the specific name *flavipennis* having priority.

Chnaunanthus discolor Burm.

Chnaunanthus discolor Burmeister, Hand. Ent. 4: 32, 1844.—Bates, Biol. Cent. Amer., Col. 2(2): 130, 1887.—Dalla Torre, Coleop. Cat. 45: 7, 1912.

The main specific characters are given in the key and the male genitalia are shown on the plate. This species varies considerably in color, the elytra ranging from entirely testaceous, through testaceous with black cloudings on the disc, to almost entirely piceocastaneous; the thorax may be piceorufous, rufous with testaceous marks on the lateral margins, or may (rarely) be almost entirely testaceous.

Apparently confined to Mexico and Lower California; I have examined 65 specimens from Mexico, all taken in the late fall. I have also seen two specimens from San Jose del Cabo in Lower California (Fuchs collection) in the United States National Museum.

Chnaunanthus chapini Saylor, n. sp.

Male.—Size, shape and many characters exactly the same as in *Ch. discolor*. Head with front smooth at base, coarsely densely punctured apically; clypeus coarsely punctured, apex reflexed, emarginate. Thorax finely moderately densely punctured, disc glabrous (due to wear?); hind angles subangulate but hardly obvious, side margins ciliate. Elytra with sparse erect hairs. Pygidium convex, polished, densely hairy in basal half, smooth at apical half. Abdominal segments connate, with the sutures hardly obvious, sixth segment free.

Female.—Head with front entirely punctured; pygidium flattened, polished, sparsely hairy in apical two-thirds, subglabrous apically; otherwise similar to male. Length 3.5–4 mm.

Holotype and allotype (U.S.N.M. no. 5227) are from Panamint Valley, Death Valley, California, and were collected in April 1891 by A. Koebele. A single paratype male, in the author's collection, is from Oregon, collected in July, and probably came from the arid parts of that state.

I take pleasure in naming this species in honor of Dr. E. A. Chapin of the National Museum as a slight token of my appreciation for many favors.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE ACADEMY

RECENTLY ELECTED TO RESIDENT MEMBERSHIP IN THE ACADEMY

LLOYD VIEL BERKNER, physicist, Department of Terrestrial Magnetism, Carnegie Institute of Washington, in recognition of his contributions to the physics of the earth's outer atmosphere, particularly the development of methods and measurement of outer atmospheric ionization, and the study of the relation of this ionization to solar and geophysical effects and to radio wave propagation.

A. HAROLD BLATT, associate professor, Howard University, in recognition of his achievements in organic chemistry.

WILBUR S. BURBANK, geologist, Section of Metalliferous Deposits, U. S. Geological Survey, in recognition of his contributions to petrology and economic geology, in particular, his researches on the structural geology of Colorado.

EDWARD A. CHAPIN, curator of insects, U. S. National Museum, in recognition of his contributions to systematic entomology, especially the taxonomy of the Scarabaeidae.

WILLIAM RIDGELY CHAPLINE, principal inspector of grazing, U. S. Forest Service, in recognition of his contributions to forestry research, especially range research and erosion control.

JESSE ROY CHRISTIE, associate nematologist, Bureau of Plant Industry, in recognition of his work in zoology, parasitology, and phytopathology.

MAYNE REID COE, associate chemist, Bureau of Chemistry and Soils, in recognition of his researches on the effect of the various wave lengths of light upon the development of rancidity of oil-bearing foods.

HARRY DIAMOND, principal physicist, National Bureau of Standards, in recognition of his contributions to safety in aerial navigation, in particular, the development of aids in blind flying and blind landing.

PAUL F. DICKENS, associate in medicine in George Washington University Medical School and Chief of Medical Service, Gallinger Hospital, in recognition of his researches in circulatory and respiratory diseases.

ROLLA EUGENE DYER, assistant director and chief of the Division of Infectious Diseases, National Institute of Health, in recognition of his contributions to medical science, in particular, his researches on typhus fever.

WALTER FREEMAN, professor of neurology, George Washington University Medical School, in recognition of his researches in neurology and neuropathology.

KARL F. HERZFELD, professor of physics and head of department, Catholic University, in recognition of his outstanding contributions in physics and physical chemistry.

WALTER C. HESS, assistant research professor of chemistry, Georgetown

University, in recognition of his contributions to the field of biological chemistry, especially the chemistry of the biologically important sulfur compounds.

ANNA I. JONAS, associate geologist, U. S. Geological Survey, in recognition of her work in the geology of the crystalline schists.

MYRNA FRANCES JONES, zoologist, Division of Zoology, National Institute of Health, in recognition of her contributions to parasitology, especially the life histories of bird tapeworms and their invertebrate hosts.

ANNIE M. HURD-KARRER, associate physiologist, Bureau of Plant Industry, in recognition of her work on plant physiology, especially on disease resistance of plants, seed disinfection, properties and buffer systems of plant sap, absorption of selenium by wheat, and the protection from selenium injury given by sulfur.

THEODORE KOPPANYI, professor of pharmacology and chairman of the department, Georgetown University, in recognition of his researches in pharmacology.

SAMUEL HENRY MCCRORY, chief, Bureau of Agricultural Engineering, in recognition of his contributions to agricultural engineering.

ALBERT R. MERZ, chemist, Bureau of Chemistry and Soils, in recognition of his achievements in the field of agricultural and fertilizer chemistry.

HOWARD E. MIDDLETON, senior soil conservationist, U. S. Department of Agriculture, in recognition of his contributions in soil physics and chemistry.

BEN HARRY NICOLET, senior chemist, Bureau of Dairy Industry, in recognition of his contributions to organic chemistry.

PAUL WILSON OMAN, assistant entomologist, Bureau of Entomology and Plant Quarantine, in recognition of his work on leaf hoppers.

JOHN W. ROBERTS, principal pathologist, Bureau of Plant Industry, in recognition of his researches on the diseases of apples, peaches, plums, and cherries.

ROSCOE ROY SPENCER, senior surgeon, U. S. Public Health Service, in recognition of work in bacteriology and especially for his discovery of the vaccine for Rocky Mountain spotted fever.

LLOYD A. SPINDLER, associate zoologist, Bureau of Animal Industry, in recognition of his contributions to parasitology.

ALAN STONE, associate entomologist, Bureau of Entomology and Plant Quarantine, in recognition of his contributions to the biology and taxonomy of Diptera.

JAMES STEELE WILLIAMS, associate geologist, U. S. Geological Survey, in recognition of his work on the carboniferous faunas and formations of the central and western United States.

WILLARD HULL WRIGHT, senior parasitologist, National Institute of Health, in recognition of his contributions in the field of therapeutics of diseases caused by internal parasites.

PHILOSOPHICAL SOCIETY

1110TH MEETING (continued)

F. G. BRICKWEDDE: *Some recent investigations of ortho- and para-hydrogen at low temperatures.*—Hydrogen, of atomic weight one, is a mixture of ortho- and para-hydrogen (o-H_2 and p-H_2) in varying concentrations. Since the properties of o- and p-H_2 differ, the properties of hydrogen are variable. The hydrogen vapor pressure thermometer which is used to measure temperatures in the range of liquid hydrogen temperatures, 13.9 to 20.4°K, is therefore, subject to variation, and the experiments which formed the subject of this report were undertaken by R. B. Scott and the speaker in the Cryogenic Section of the National Bureau of Standards for the purpose of finding ways to improve the reliability of this instrument. The results were reported, however, from the point of view of the information they reveal concerning the fundamental differences between the condensed phases of o- and p-H_2 responsible for the observed differences in properties.

The change with temperature of the difference between the vapor pressures of p-H_2 and n-H_2 (normal hydrogen whose composition is 75 percent o-H_2), dP/dT reveals a difference between the *lattice* energies of p- and n-H_2 in a condensed phase, the energy of liquid p-H_2 being 2.4 cal mol^{-1} greater than the energy of liquid n-H , and the energy of solid p-H_2 5 cal mol^{-1} greater than that of solid n-H_2.

The change of the *lattice* energies of liquid solutions of o- and p-H_2 with the composition reveals a large deviation from the law of ideal solutions which states that differences in the properties of solutions are proportional to the differences in the composition. The vapor pressure data lead to the following equation which represents the dependence of the internal or lattice energy of solutions of o- and p-H_2 upon the concentration:

$$dE_s/dx_1 = E_1 + (1 + a_{1,2}x_2)$$

where E_s is the energy per mol of solution whose composition is given by the mol fraction $x_1 = 1 - x_2$, E_1 is the energy per mol of pure variety 1, and $a_{1,2}$ is an empirical constant different in value from $a_{2,1}$.

The densities of liquid p-H_2 and n-H_2 differ by 0.5 percent. Orthohydrogen, the freely rotating variety, has a smaller molecular volume and internal energy than p-H_2, the non-rotating variety. The direction of these differences is opposite to the direction of the changes observed in other substances in passing through the transition from the state in which the molecules are oriented to the state in which they rotate freely. The application of the Heisenberg Uncertainty Principle to the problem shows that the p-H_2 molecules are not aligned in any preferred direction but rather that the orientation of the axes of p-H_2 molecules are randomly distributed over all possible directions. The state of molecular orientation in liquid and solid p-H_2 corresponds, therefore, with that of free rotation in other substances. The rotating o-H_2 molecules are oriented, their state corresponding more nearly with that of oriented non-rotating molecules in other substances.

The difference in the intermolecular forces in liquid or solid p-H_2 and o-H_2 arises, because of the difference in the distribution of the electron density of p-H_2 and o-H_2 molecules. The electron distribution of a p-H_2 molecule at liquid hydrogen temperatures ($j = 0$) is spherically symmetrical. For o-H_2 molecules ($j = 1$) the electron density is greatest either along an axis ($m = 0$) or over a plane ($m = \pm 1$).

The ortho-para vapor pressure difference of deuterium was compared with

that of hydrogen. The ratio of the difference in the vapor pressures of the non-rotating variety and the normal mixture to the product of the change in the ortho-para composition and the vapor pressure of the normal variety,

$$\left[\frac{\Delta P(p\cdot H_2 - n\cdot H_2)}{0.75p(n\cdot H_2)} \text{ for } H_2, \text{ and } \frac{\Delta P(o\text{-}D_2 - n\cdot D_2)}{0.33P(n\cdot D_2)} \text{ for } D_2\right],$$

is about the same for H_2 and D_2. If, however, the differences in vapor pressures are compared subject to the condition that the change in the composition of the rotating and non-rotating varieties is the same for H_2 and D_2, it is found that $\Delta P/P$ is larger for D_2 than for H_2. The difference in the lattice energies of a condensed phase of ortho and para varieties depends upon d/dT of $(\Delta P/P)$. The vapor pressure data lead to a smaller ortho-para lattice energy difference for D_2 than for H_2.

The vapor pressure of freshly condensed normal hydrogen increases with time because of the conversion of o-H_2 to p-H_2, the rate being 0.2 mm per hour. The rate of increase of the vapor pressure decreases as the concentration of o-H_2 decreases in accordance with a bimolecular reaction of o-H_2 molecules. The rate of change of the vapor pressure of n-D_2 is so small that it was beyond the accuracy of our experiments to detect it, the experiments setting as an upper limit for the change 10^{-3} times the rate of change of the vapor pressure of n-H_2. Conversion in the condensed phases of hydrogen and deuterium results from the *collision* of rotating molecules with paramagnetic molecules. The o-H_2 molecules, and the p-D_2 and 5/6 th of the o-D_2 molecules are paramagnetic, whereas the p-H_2 and 1/6 th of o-D_2 molecules are diamagnetic and hence are ineffective in bringing about conversion. The probability of conversion upon *collision* of two molecules is proportional to the square of the force of interaction of their magnetic moments, and thus approximately proportional to the 4th power of the magnetic moments of the nuclei. The magnetic moment of the proton is about 2.9 Bohr nuclear magnetons, whereas the magnetic moment of the deuteron is about 0.75. Taking into account the difference in the ortho-para composition of n-H_2 and n-D_2 a calculation shows that the rate of change of the vapor pressure of n-D_2 may be expected to be of the order of 10^{-3} times the rate of change of the vapor pressure of n-H_2, which is in accord with the experiments. The average magnetic moment of o-D_2 is greater than that of p-D_2 and, hence, it is to be expected that the order of the conversion reaction p-D_2 to o-D_2 is more nearly first order than second order. (*Author's Abstract.*)

H. E. MCCOMB, *Recording Secretary*

Obituary

LORD ERNEST RUTHERFORD, noted British physicist, died October 19, 1937, at Cambridge, England.

He was born at Nelson, New Zealand, August 30, 1871. Educated at Nelson College, Canterbury College, New Zealand University, and Cambridge University, he received in succession the M.A., B.Sc., and B.A. degrees. New Zealand University conferred upon him the D.Sc. degree in 1901, and many domestic and foreign universities honored him during his subsequent career.

Lord Rutherford lectured at McGill University, the University of Manchester, and Trinity College, of which he was a Fellow. Since 1919 he was Cavendish Professor of Experimental Physics and Director of the Cavendish Laboratory, University of Cambridge. He was also Professor of Natural Philosophy, Royal Institution, and Chairman of the Advisory Council of the Department of Scientific and Industrial Research since 1930. His life's work and many publications dealt chiefly with the problems of radio-activity. He was the pioneer of the modern school concerned with the splitting of the atom and the transmutation of the elements. For his great achievements he received the Rumford, Copley, Barnard, Franklin, Albert, and Faraday medals; the Bressa Prize from the Turin Academy of Science; and the Nobel Prize for Chemistry, 1908.

Lord Rutherford was President of the British Association for the Advancement of Science, 1923; and President of the Royal Society, 1925–1930. He was knighted in 1914 and raised to a barony in 1931. He was an honorary member of the Washington Academy of Sciences.

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